BEST PRACTICES FOR BUILDING AND MAINTAINING UNIVERSITY-INDUSTRY RESEARCH PARTNERSHIPS: A CASE STUDY OF TWO NATIONAL SCIENCE FOUNDATION ENGINEERING RESEARCH CENTERS

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Frank Carl Boschi
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ABSTRACT

Technology transfer involves the transfer of knowledge and inventions to the corporate sector, and has contributed to an increase in university and industry partnerships. The passage of the Bahy-Dole Act in the early 1980s, greatly assisted university-industry partnerships, generated the use of knowledge and inventions that came out of government sponsored research, and allowed universities to retain the intellectual properties instead of the federal government.

In 1985, the NSF initiated the Engineering Research Center (ERC) Program to develop additional university-industry partnerships. The NSF intention is that Engineering Research Centers will become self-sustaining after the eleven years of NSF funding with an increase of research partnerships with industry and other federal agencies.

This dissertation is a comparative case study of two NSF Engineering Research Centers. The Center for Biofilm Engineering (CBE), at Montana State University, that has graduated from NSF funding, and has become a self-sustaining research Center with 23 current industrial members. The second ERC is the University of Michigan, Center for Wireless Integrated MicroSystems, which is in the fourth year of NSF funding with 19 industrial members. The main question that was answered in the comparative case study is what are the best practices that resulted in building and maintaining industrial partnerships?

Center faculty market the ERC through their publications, and presenting at conferences where industrial representatives are informed of Center research. Other methods are visiting company sites, producing quality research, inviting industrial personnel to the ERC to meet with faculty and to attend ERC workshops. The elicitation of the company research problem from industrial personnel by Center faculty is important for maintaining Center membership. Multiple champions within the company must be cultivated to insure against losing a champion to retirement or company transfer.

The Center Director of the CBE publishes and travels extensively to conferences and provides the best leads, while the Center for WIMS faculty thrust leaders, and the UM Corporate Relations personnel provide the best leads for prospective new members.

Industrial members mainly join an ERC for knowledge, to perform collaborative research with faculty, and to have access to faculty and students.

CHAPTER 1

INTRODUCTION

Technology transfer, involves the transfer of knowledge and inventions to the corporate sector, and has contributed to an increase in university and industry research partnerships. In return, the universities receive revenue from the royalties paid by the corporations for research and inventions that were created by their faculty (Novis, 1993).

The transfer of knowledge and technology from university research centers to corporations are methods used to secure industrial funding for research at universities through industrially sponsored research or/and through Center membership to NSF Engineering Research Centers (ERC).

In the early 1980s, new federal legislation greatly helped to enhance university and business partnerships with the passage of the Bahy-Dole Act (Novis, 1993). The purpose of the legislation was to generate the use of the knowledge and inventions that came out of government sponsored university research, and allow universities to retain the intellectual properties instead of the federal government (Novis, 1993). This allowed industry to gain knowledge from university basic research, and to license university inventions (Novis, 1993).

In 1985, the NSF initiated the Engineering Research Center (ERC) Program to develop more university-industry research partnerships to strengthen the competitive position of U.S. firms in world trade (NSF, 2003). ERCs are funded by the NSF for eleven years, and the total annual funding for each Center ranges from $3.1 million to

$19.4 million, with NSF's contribution ranging from $2.0 to $2.9 million per year. The NSF intention is that the ERCs will become self-sustaining after the eleven years of funding, with an increase of research partnerships with industry and other federal agencies. Many of the Centers dissolved after the NSF funding expired, while other Centers continued to thrive (NSF, 2003).

Problem

Recent experience in the NSF ERC Program has shown that most graduating ERCs do not survive. Many have dissolved since 1997, when significant numbers of ERCs began to graduate from NSF funding (Costerton, 2002). Why did some Centers continue to thrive and become self-sustaining, while other Centers dissolved? Some of the Centers that survived and became self-sustaining implemented successful practices in developing and maintaining research partnerships with corporations. There are currently, sixteen self-sustaining Engineering Research Centers (ERC) in the U.S.

The Center for Biofilm Engineering (CBE) at Montana State University (MSU) was established in 1990, and graduated from NSF funding in 2001. The Center has been self-sustaining since 2001, and has 23 industrial members sponsoring the Center. The University of Michigan (UM) Center for Wireless Integrated Microsystems (WIMS) was established in 2000, and has industrial support from 19 companies committed to their Center. The comparative case study of the two NSF Engineering Research Centers (ERC), a self-sustaining Center and an ERC in the fourth year of NSF funding, describes Center practices that have contributed to building and maintaining many Center-industry

research partnerships.

Although there is abundant literature on the broad field of university-industry research relations, there is a limited research base on the subject of the NSF's ERC practices for building and maintaining industrial research partnerships. Therefore, since the NSF's ERC Program was designed to create long-term collaborations between ERCs and industry by building and maintaining research partnerships, the comparative case study identified the practices that were more successful in building and maintaining partnerships, and concurrently, identified the unsuccessful practices.

University basic research plays a large role in much of the entrepreneurial activity in the field of biotechnology. Over 70% of the university income received from the licensing of university inventions to industry has come from the life sciences, and the biotechnology sector has become the largest generator of licensing income (AUTM, 1998). Since universities are searching for funding from industry, and they possess what industry usually wants and needs, graduate students and research knowledge, they must improve their marketing methods for their products. The use of best practices to build Center-industry research partnerships can be improved during the biotechnology and wireless micro-systems revolution.

Federal and state agencies have been the major sponsors of university research, however as research costs have increased, universities have turned to industry to finance their research. Establishing university-industry research partnerships is a common method for financing and conducting basic and applied research, however, universities and industry possess different cultures and objectives (Burnham, 1997).

The current economic climate and the reduction of corporate Research and Development (R&D) expenditures increased the need for university-industry research partnerships. In order to finance and enhance their quality of research and teaching programs, some universities are aggressively seeking additional industry funding, and companies are seeking universities for their basic research needs and technologies. In addition, industrial companies use the availability and quality of university research as factors for new high-tech facilities (Gibson et al., 1988).

With current downsizing of industrial personnel and increased outsourcing of R&D, companies expect quick results in solving their specific industrial needs when they invest in university research. Industrial funds usually are for basic and applied research projects at universities that contribute to corporate objectives and missions (Fusfeld, 1999).

It is difficult for university and industrial personnel to develop the close interactions that are necessary to become a contributor to industrial developments, and concurrently, pursue basic research. It requires good management from industry, the willingness of university researchers to consider the relation of their research to external developments, and patience by both cultures. Universities can maintain their strength in basic research by building and maintaining relationships with industrial partners. Industrial partners use academic partners to integrate the basic research activities of universities with the strategic needs and internal R&D of the company.

Given the capabilities of the research university and the strength of U.S. industrial research, the development of effective working relationships between university and

industrial personnel can provide a competitive advantage for the United States. There are differences in the objectives and missions of university and industry, and there can be misunderstandings and confusion. University objectives and missions are to generate science for the benefit of society, while industry is profit oriented. Therefore, each culture has to understand and accept the strengths and the motivations of the other, and appreciate the unique functions that each provides for society.

Purpose

The purpose of the case study was to describe the best practices for building and maintaining ERC-industry research partnerships, from the comparative case study of two NSF Engineering Research Centers (ERC) and their 42 industrial members. Many ERCs that have graduated from eleven years of NSF funding, have dissolved because they were not able to obtain or maintain Center memberships from industrial members. The case studies described the best practices from two NSF-ERC's, one that has graduated from NSF funding and has continued to be self-sustaining, and the other in the fourth year of NSF funding.

The case study was conducted through interviews of Center Directors, Industrial Liaison Officers, Center faculty, and university technology Licensing Officers, who are responsible for university intellectual properties. Surveys were given to all industrial members who were in attendance at Technical Advisory Conference (TAC) meetings in July and October 2003. In addition, NSF-ERC site visit documents from both Centers were collected and analyzed for marketing methods for improving ERC-industry research

partnerships. The Centers for the case studies were the Center for Biofilm Engineering (CBE) at Montana State University (MSU), and the University of Michigan (UM) Center for Wireless Integrated MicroSystems.

The National Science Foundation

The National Science Foundation (NSF) was created in 1950 to promote and advance progress in science and engineering research and education in the United States. It is the only federal agency whose mission covers science, engineering research, and education (NSF, 1997b). Its purpose is to ensure that the United States maintains leadership in discovery, learning and innovation across science, mathematics and engineering. The National Science Foundation's (NSF) activities are guided by the National Science Board (NSB) (NSF, 1997a).

History of the NSF Engineering Research Center Program

The goal of the Engineering Research Center (ERC) Program is to develop fundamental knowledge in engineering fields that will enhance the international competitiveness of U.S. industry and prepare engineers to contribute through better engineering practices.

The ERC Program grew out of concern expressed in the early 1980s by the National Academy of Engineering (NAE) and the National Science Foundation (NSF) that: (1) technological advances were occurring at the intersection of engineering and other disciplines, requiring a cross-disciplinary approach to engineering that had not been

introduced into engineering research or practice; and (2) an inaccurate methodology had developed in how engineering was carried out in industry and how students were being trained at universities (NSF, 1997a). Additionally, the NAE wanted to improve engineering research and education that would better prepare students for employment with U.S. companies, and assist industry in becoming more competitive in world markets.

In 1985, the NSF established the Engineering Research Center (ERC) Program to develop a government-industry-university partnership to strengthen the competitive position of U.S. firms in world trade, and change the culture of engineering research and education in the U.S. The main problem was the need to increase the productivity of U.S. industry in an increasingly global economy. The ERC Program was designed to create long-term collaborations between universities and industry, create new industry-relevant knowledge, and prepare new engineering leaders who are more capable of engaging in team-based, cross-disciplinary engineering practices (NSF, 1997b).

ERCs provide an environment for academics and industrial personnel to focus on advances in complex engineering systems. The activity within ERCs lies in the discovery of science and the innovation of engineering, creating a synergy between science, engineering, and industrial practice. The ERCs provide industrial personnel the opportunity to collaborate with faculty and students in solving scientific challenges, which provides the knowledge base needed to generate advances in technology (CBE, 2001). Since 1985, the National Science Foundation funded approximately 32 ERCs (NSF, 2003).

National Science Board Report

A National Science Board (NSB) report emphasized two trends of interest in the development of national policy involving the capability of U.S. industry to develop new products and processes. The first was funding trends, and the restoration of funding by U.S. industry of its own research. This represented a turnaround from the cutbacks that began in the late 1980s, with small industrial investment in basic and applied research at universities and colleges (NSB,1998).

The second finding suggested that patents granted in the U.S. patent system are increasingly linked to public research, and that the inventors in five industrial nations, including the United States, are taking advantage of the results of research performed in universities, government laboratories, medical schools, and nonprofit organizations. This is apparent in sectors where there have been many new start-up companies, such as biotechnology and pharmaceuticals. U.S. inventors have reported that the journal publications that were cited for their inventions, were mainly produced by U.S. authors. The drug industry has depended upon academic research for 44% of its new products and 37% of its processes (Bremer, 1993).

Industrial investments in research and industry's use of publicly funded research are growing. The investments by industry and government continue to compliment each other, with public investment in basic research serving as a forerunner to private sector investment in the areas of applied research and development (NSB, 1998).

The decline in the amount of federal government R&D funding has led to a slightly declining amount of R&D expenditures over the past five years. As the federal

government has reduced the funding of basic R&D research, industry proportionately increased its developmental R&D funding. This resulted in a change in research activities within the U.S. resulting in less basic and applied research and more developmental research. Industry spends heavily on the development and commercialization of technologies, while the federal government, academia, and other nonprofit organizations spend heavily on basic research (Degnan, 1998).

Organizations in the U.S. spent $284 billion for R&D research in 2003, with 68% of the total R&D performed by industry, 14% by universities, 9% by the federal government, and 5% was performed by non-profit agencies. Industry funded 63 % of the total R&D expenditures, the federal government funded 30%, universities funded 4%, and 3% was funded by nonprofit organizations (NSF, 2004). The private-public funding split is a large change from cold war levels when the U.S. government funded 66% of all R&D expenditures (NAE, 1997).

For 2003 R&D expenditures, basic research represented 19 %, applied research 24 %, and development represented 57 %. Universities performed 55.3 % of the basic research, while the federal government funded 60.5 % of the basic research performed by the universities. In contrast, industry devoted only 5% of its total R&D support for basic research, but funded $2.8 billion of university research, which was up 5.2% from 2002 (AUTM, 2003). The need for short-term profits, downsizing, and the cost of performing research are the reasons for industry's reduction in basic R&D. Currently, industry focuses on applied R&D, and by leveraging resources at universities, industry maximizes its research investments.

University of Michigan Center for Wireless Integrated MicroSystems

The University of Michigan (UM) Center for Wireless Integrated MicroSystems (WIMS) is focused on miniature integrated micro-systems capable of measuring a variety of physical parameters, interpreting the data, and communicating with a host system over a bi-directional wireless link.

The Center for WIMS research program anticipates eleven years of funding from the NSF, the University of Michigan (UM), industry, and private foundations. Numerous companies, ranging from multi-billion dollar corporations to small start-ups, partner with WIMS. The Center has 19 current industrial members, and the annual Center membership to the industrial program is $50,000. The companies provide financial resources, perform research at the UM, license Center for WIMS technologies, spin-off new companies, transform Center inventions into products, and provide jobs for Center students.

The Industrial Partnership Program at the Center for WIMS includes companies in micro-electronic, micro-electro-mechanical, wireless communications, automotive, environmental, and medical fields. Currently, the Center is in its fourth year of NSF funding, and has 19 industrial members. The Center for WIMS major research areas are in micro-power circuits, wireless interfaces, environmental sensors and subsystems, biomedical sensors and subsystems, and micro-packaging.

The Center for Biofilm Engineering - Montana State University

The Center for Biofilm Engineering (CBE) has completed eleven years of experience integrating research, education and industrial concerns. The Industrial Associates Program promotes direct involvement in planning and collaborating on research programs, as well as individual research projects, covering a variety of biofilm applications from controlling infections on medical devices to enhancing biodegradation of hazardous compounds in the environment (CBE, 2000).

Researchers at the Center investigate biofilm related phenomena in applications ranging from the bioremediation of contaminated groundwater and the efficient production of clean drinking water, to the control of microbially influenced corrosion and of infections on medical devices. Multi-disciplinary teamwork and industrial participation are key to the success in developing the technology and methods needed to manage biofilms in a wide range of applications (CBE, 2000).

Industrial participants in the Center profit most from close interaction with Center research and activities. An Industrial Associates Program features regular meetings with the Center faculty, access to research results, and consultations with Center researchers. The Center membership to the Industrial Associates Program is $20,000 per year, and there are numerous opportunities for sponsored research (CBE, 2000).

Many opportunities are available for industrial members to increase their involvement in the Center. The Industrial Associates Program offers an option to expand participation to a partnership level with the Center. The Partnership Program enables companies to make a major commitment to the Center through personnel exchanges,

graduate student support and sponsored research. An Industrial Associate can contribute to the Center through an endowment of an academic or research chair to address a problem of national concern or a problem of specific interest to the sponsoring company (CBE, 2000).

Context of the Problem

Initiating and maintaining university-industry research partnerships requires much effort from academic and industrial personnel who are from different cultures with different objectives, missions, and work within different timeframes. Industry is seeking access to Center faculty and research to solve specific company problems, and to employ well-trained students. ERCs are seeking access to industrial funds for infrastructure, research, and opportunities for ERC students to be employed by industry. Center research by faculty leads to inventions, and the licensing of university inventions becomes profitable for some universities (Trune, 1996). Innovative methods to attract industrial funds are increasingly used to enlist industrial members. Other ERCs have dissolved after exhausting eleven years of NSF funding, and are unable to sustain industrial funding.

Key legislative acts and the rise of R&D in biotechnology increased the number of research universities with offices of technology transfer, and has increased the revenue of some offices since the early 1980s (Mowery et al, 1999). Since 1980, 4,081 new companies have been formed based on a license from an academic institution (AUTM, 2002). Over 3,933 U.S. patents were issued to universities in 2003, and university licensing income received from licenses and options was $1.3 billion. In 2003, sponsored

research expenditures by industry were $2.8 billion, which was 5.2% larger than in 2002 (AUTM, 2003).

ERC-industry partnerships are helping to move new inventions from ERCs to companies, and to the market. Numerous inventions from ERCs are transferred to industry, which led to advances in the medical, engineering, chemical, computing, and software industries (AUTM, 1998).

Research Questions

The main research question that was answered from the case study was what are the best practices for building and maintaining of ERC-industry research partnerships? A second question that was answered was what are the unsuccessful practices for building and maintaining Center-industry research partnerships? The questions proposed to Center Directors (CDs) sought the methods for obtaining the leads in finding prospective industrial members, methods for attracting and maintaining industrial memberships, the CD's Center vision to industry and university administrators, the amount of Center patents, technologies transferred to industry, start-ups, and policies pertaining to exclusive licensing, and alliances with other universities and federal agencies.

The questions for ILOs sought the methods for building and maintaining Center-industry partnerships, methods that were unsuccessful, type of systems used for tracking of prospective industrial members, the methods for identifying companies to approach for Center membership, and sources of leads for contacting prospective industrial members.

The questions proposed to Center faculty sought the originator of the Center-

industry relationships by identifying the personnel who initiated first contact between Center and industrial members, if prior consulting and research projects assisted in membership, and if the Center ILO asks the Center faculty for leads. Additional questions asked for the methods that improve and maintain Center-industry research partnerships, methods that were unsuccessful, and if students were influential in the enlistment of industrial members.

The questions proposed to the LOs responsible for Center intellectual properties (IP) described the sources of industrial leads for licensing of Center innovations, the university policies that enhance the licensing of ERC innovations, and if the granting of exclusive licenses improved the licensing of Center innovations.

The questions proposed to industrial members described the industrial reasons for joining and maintaining research partnerships with Centers, the sources of leads for initiating the partnerships, methods to improve the marketing of the Center to industry, industrial methods for finding university research to support, the university inhibitors to partnering with ERCs, and the most and least valued aspects of ERC-industry research partnerships.

Significance of the Problem

New ERCs are funded by the NSF, and are expected to become self-supporting after eleven years of federal funding. Since the start of the ERC program, many of the ERCs have dissolved after completing their federal NSF funding cycle, but others become self-supporting. This is a result of the development of Center practices that

established a large industrial membership, which increased funding for research, graduate students, and continued to keep the Centers from being dissolved. ERCs increased their patent activity, demonstrating that inventions are moving from Center research to industry.

Personal Statement

The researcher has a science background with a degree in geology, with experience in the corporate oil sector while employed as a petroleum geologist. Additional internships at the Center for Biofilm Engineering (CBE), and Montana State University (MSU) Techlink provided the researcher with experience and background into the fields of biotechnology and technology transfer. The researcher additionally, is a doctoral student in higher education administration at MSU, and is specializing in technology transfer of university inventions to the corporate sector. The researcher has the desire to assist academic inventors in moving their innovations to the corporate market, and bring a royalty return to the inventor and to the institution. The researcher has continual association with the CBE since 1998, and attended several Technical Advisory Conferences (TAC) at MSU, and met many of the industrial members of the CBE.

The Limitations and Delimitations of the Case Study

The limitations of the case study were contingent on the responses of the participants of the survey and the participants of the interviews. Not all the intended

participants attended the Technical Advisory Conferences in the Summer and Fall of 2003, and some participants declined to answer the survey or not return the survey. The delimitations of the study were the researcher's selection of the two NSF-ERCs, the participants, the survey instrument, the open-ended interview questions, and the selection of NSF-ERC site visit documents to be reviewed. The researcher asked almost similar questions to each of the participants at each of the Centers, and attempted to maintain the same procedures and mannerisms during the course of the interviews.

Definition of Terms

Applied Research: Relatively short to medium duration research projects, which emphasize the goal of bringing research to the commercial market (Novis, 1993).

AUTM: Association of University Technology Managers; a non-profit association with membership of more than 3,000 technology managers and business executives who manage intellectual property; one-third of the most active growth sectors of the U.S. economy. AUTMs membership represents over 300 universities, research institutions, teaching hospitals, and a similar number of companies and government organizations (AUTM, 2000).

Basic Research: Relatively long duration which emphasizes the goal of developing new research at the forefront of scientific discovery, which typically is underdeveloped and years away from being marketable (Novis, 1993).

Biofilms: Biofilms are populations of microbial cells that are concentrated at an interface (usually solid/liquid) and typically surrounded by an extracellular polymeric

slime matrix (Stoodley, 2000).

Biotechnology: The use of living organisms to carry out defined chemical processes for industrial application (Madigan, Martinko, and Parker, 2003).

Breakthrough Innovation: Innovation that cannot be compared with any existing practices or inventions; technology is so new that it creates a new product class (Mohr, 2001).

Breakthrough Technology: A technological advance that does more than build incrementally on earlier technology. A breakthrough technology causes a significant advance in the science (Gulbrandsen, 1999).

CBE: Center for Biofilm Engineering, Montana State University, Bozeman.

DARPA: Defense Advanced Research Projects Agency.

Disclosure: An initial filing of a researcher's invention with the appropriate university office, usually the technology transfer office, with the intention of having the invention patented and then licensed to industry (Novis, 1993).

Disrupting Technology: Technology that can cause existing products or processes to become immediately obsolete.

DNA: Deoxyribonucleic acid.

DOE: U.S. Department of Energy

Entrepreneurial Culture: Exhibits high levels of risk taking, dynamism, and creativity (Hellriegel, 1999).

ERC: Engineering Research Center: A NSF funded academic Engineering Research Center, which provides an integrated environment for academic and industry

personnel to focus on next-generation advances in complex engineered systems.

FFERDC: Federally Funded Research and Development Center.

IGERT : Integrated Graduate Engineering and Research Training Program; IGERT is an NSF wide endeavor developed to meet the challenges of educating Ph.D. scientists and engineers with the multi-disciplinary backgrounds and the technical, professional, and personal skills needed for the career demands of the future. The program is intended to catalyze a cultural change in graduate education, for students, faculty, and universities, by establishing new, innovative models for graduate education in a fertile environment for collaborative research that transcends traditional disciplinary boundaries. It is intended to facilitate greater diversity in student participation and preparation and to contribute to the development of a diverse, globally aware, science and engineering workforce.

Intellectual Property: The products of human ingenuity, which can be owned and dealt with as a form of property because of a body of laws. These laws give to the owner of the intellectual property the right to stop others from using the invention or other subject matter of the intellectual property without his or her permission (Licensing, Executives Society, 2000).

Intrapreneur: Someone in an existing organization who turns new ideas into profitable realities.

License: Authority or liberty given to do or forbear any act; especially, a formal permission from the proper authorities to perform certain acts or to carry on a certain business (Manfroy, 2002).

Marketing: The process associated with promoting for sale goods or services. The classic components of marketing are product, price, place, and promotion (Imber, 2000).

MTBRC: Montana Board of Research and Commercialization.

NAE: National Academy of Engineering: It is a private nonprofit institution that promotes the technological welfare of the U.S. by marshaling the knowledge and insights of eminent members of the engineering profession. The NAE advises the federal government and also conducts its own independent studies that examine topics in engineering and technology.

NSB: National Science Board; Monitors the health of the Nation's science and engineering programs and advises the President and Congress on policy matters pertaining to research and education in the sciences and engineering.

NSF: National Science Foundation; the NSF is an independent agency of the U.S. government. The Foundation consists of the National Science Board of 24 part-time members and a Director, each appointed by the President with the advice and consent of the U.S. Senate, and eight Assistant Directors. The Act established the NSF's mission: to promote the progress of science; to advance the national health, prosperity, and welfare; and to secure the national defense.

Patent: An agreement between an inventor and the public, which provides that, in return for a full disclosure of the invention, the inventor is granted the right, for a fixed period of time, to exclude others from making, using, or selling the disclosed invention in the U.S. Its main purpose is to encourage disclosure so that once the monopoly expires, the public may have unrestricted access to the invention. The *utility patent* protects the

utility or function of a device, is valid for 20 years from the date of application. The *design patent* protects the design or appearance of a device is valid for 14 years from the date it was granted (Kassatly, 1995).

Platform Technology: A technology that supports not only many different applications but different levels of applications. For example the Cohen-Boyer, recombinant DNA gene splicing techniques can be used in research, diagnostic, therapeutic, and agricultural applications (Gulbrandsen, 1999).

REU: The Research Experience for Undergraduates Program sponsored by NSF.

Size of a Technology: Determinants of a technology's size include magnitude of advantage over current new methods; size of potential market; cost and time to development; patentability; and appropriability, which is the ability of a private firm to protect profits from an invention). Sizes of Technology are segmented by:

Large: Major innovations for obvious (blockbuster) or less foreseeable (disruptive technologies) markets.

Medium: Innovations that are significant enough to support a start-up company or a new line of products for an existing company.

Small: Innovations that probably are too small to support a start-up, but adequate for a product in an existing firm.

Stage of Development: Stage is a component of potential technology value, and it describes where a technology stands on the commercialization path, ranging from theory-only to refined prototype. Stage includes dimensions of technical and market feasibility/risk.

Embryonic/Uncertain Stage: Innovations with potential commercial feasibility, but with concepts as yet unproven.

Patent: Patents are property rights that enable the patent owner to control the making, using, or selling of technology covered by the patent. Many things are patentable, including plants, animals, and software. In the US a patent can last 17 years. (WARF, 1994).

Technology: Information that is put into use in order to accomplish some task (Rogers, 1995).

Technology Transfer: The conveyance or shift of tools, techniques, and/or legal titles used to accomplish some human purpose, (Resman, 1991).

Technology Transfer: A term used to describe a formal transferring of new discoveries and innovations resulting from scientific research conducted at universities to the commercial sector. Universities transfer technology through patenting and licensing new innovations. The major steps in this process are: (1) the disclosure of new innovations; (2) patenting the innovation concurrent with publication of scientific research; and, (3) licensing the rights to innovations to industry for commercial development (AUTM, 1998).

Technology Transfer: The application of information into use (Rogers, 1995).

Technology Transfer Effectiveness: The degree to which research-based information is moved successfully from one individual or organization to another (OKeefe,1982).

TLO: Technology Licensing Officer.

Trademark: Words, names, symbols, or devices used by manufacturers to identify their products and to distinguish them from others; often serve as an index of quality; provide protection against unscrupulous competitors who would attempt to trade on the firm's previously established goodwill and reputation by engaging in actions that confuse, deceive, or mislead the customer as to the identity of the producer of the goods. Trademarks do not offer protection against copying and selling a product that has not been patented (Mohr, 2001).

Trade Secret: Any information that is useful in the company's business, is generally unknown, is not easily ascertainable by proper means, and provides an advantage over competitors who do not know or use that information. Trade secrets are broadly defined and mean all forms and types of financial, business, scientific, technical, economic, or engineering information including patterns, plans, compilations, program devices, formulas, designs, prototypes, methods, techniques, procedures, programs, or codes; whether tangible or intangible; and whether stored physically, electronically, photographically, or in writing (Mohr, 2001).

TULCO: Triangle Universities Licensing Consortium; a cooperative Technology Transfer Center for Duke University, the University of North Carolina, and North Carolina State University.

UIRC: University-Industry Research Center

UITT: University Industry Technology Transfer.

WIMS: University of Michigan Center for Wireless Integrated MicroSystems.

CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

An examination of the literature for best practices for building and maintaining university-industry research partnerships reveals that few technology transfer dissertations or academic journals have conducted in-depth research specifically, within the university-industry sector that pertains to the NSF Engineering Research Center (ERC) Program. The most current articles relating directly to the subject are from journals distributed from technology transfer associations, and from sponsored NSF papers.

The researcher used a two-pronged definition of technology transfer for the two case studies with the transfer of artifacts, as well as the transfer of knowledge to be encompassed within the definition. Technology transfer is a term used to describe a formal transferring of new discoveries and innovations resulting from scientific research conducted at universities to the commercial sector (AUTM, 1998). An additional definition includes the transfer of the application of information into use (Rogers, 1995).

The literature review contains a brief historical perspective of university-industrial partnerships, Legislative Acts that have enhanced university-industry partnerships, institutional conflicts of interest and cultural differences, faculty conflicts of

interest, the marketing of university inventions by technology licensing offices, the industrial R&D culture and marketing of intellectual properties, technology transfer research articles that are pertinent to the building of university-industry partnerships, NSF studies of best practices of ERCs, and a summary of the review.

History of University-Industry Partnerships

Current university-industry relationships were initiated from the Morrill Act in 1862, which greatly assisted and enhanced the relationships that developed between universities, government, and industry (Allan, 1989). The legislation was enacted to fulfill the need for higher education institutions to become more involved in the social and economic development of the U.S. (Williams, 1990). The Morrill Act improved farming techniques, and assisted in transferring the U.S. from an agricultural to an industrial economy (Allan, 1989). The Act provided acreage as an endowment for agricultural colleges and established a service mission for land grant colleges (Williams, 1990).

Interactions between the business community and universities were improved by the Hatch Act of 1887, which provided federal funds for research and for agricultural experiment stations. The Hatch Act began the transfer of technology from universities when each State was funded $15,000 for establishing experimental stations that would create and assist the technology transfer (Williams, 1990). The Smith Lever Act of 1914, provided federal support for applied research in extension services for agriculture and home economics, and initiated the concept of matching funds (Allan, 1989). The Act

provided funding for the land grant colleges, and for a cooperative extension programs for the agriculture and mechanical sciences through instruction and demonstrations (Williams, 1990).

In the 1920s and 1930s, industry and private foundations were the main sources of support for university research. In order to build a state and community industrial base a significant part of research was performed by industry and the local universities (Geiger, 1989). During the 1920s, university and industry relationships generated tensions within the university environment. While university-government relationships were regarded as being in the national interest, relationships with industry were criticized as being all profit motivated (Allan, 1989). The delay of publications placed upon many research projects by the chemical industry at the Massachusetts Institute of Technology (MIT) painted the university as an industrial consulting laboratory, and not a university. Many conflicts arose and were debated over the universities conducting basic research versus practical applications for industry (Allan, 1989).

Within universities, the conflict was reduced with the emergence of the research institute, which contained its own research professors, staff, administration, and services. With support from industry, private citizens, and foundations, the research institute became a linkage between the university and industry on campuses throughout the country (Allan, 1989).

The California Institute of Technology (CIT) was developed in the 1920s through the financing from private foundations and the Southern California business community (Geiger, 1989). The university focused on basic research, and developed fields that were

relevant for local industries. While the foundations were financing academic research, numerous research relationships with industry emerged.

The use of academic faculty as consultants to industry developed out of the need for industrial laboratories to have access to academic research and faculty (Geiger, 1989). Industrial personnel became informed of the specialties and research of faculty, and their institutions. Industrial representatives were sent to visit university facilities, attended conferences, and maintained contact with key faculty. After the industrial personnel had established a relationship with the chosen faculty, the faculty were employed as consultants to remedy specific industrial problems, or became long-term consultants acting as advisors to large industrial research departments. The faculty's laboratory became an ideal location for the recruitment of personnel for industry, and faculty learned to enhance their own research programs by forming partnerships with industrial personnel (Allan, 1989).

Shortly after World War II started, relationships increased between the government and universities, with the federal government initiating programs to provide research funding for basic research. With the increase of federal funding, universities were motivated to pursue additional federal funding, and many withdrew from building industrial relationships (Allan, 1989). Some of the university laboratories jointly developed military and war inventions, with the U.S. government organizing teams of researchers from industry and universities for the federal projects (Allan, 1989).

The increase in government funding for university research continued after the war, but industry reduced investment in university research. From the 1950s until the late

1970s industrial funding was not sought by the universities because of the availability of funds from the federal government and the expansion of higher education. The time period experienced many issues concerning classified research, academic freedom, conflicts of interest by faculty, and the federal funding of national defense research at universities (Allan, 1989).

The controversy erupted in the late 1960s with violent student protests over classified federal research and industrial involvement at universities. The anti-government movement, along with federal demands for universities to be accountable for funded research, forced industry and government to rely upon their in-house research capabilities. Universities underwent financial cutbacks immediately, and cut ties on many campuses with university research institutes. Additionally, the universities launched a campaign against federal interference and regulations, and aligned themselves with industries that had experienced similar difficulties with the federal government.

In the 1970s, an emerging national research agenda provided the linkage between universities and industry. Increased partnerships between university and industry occurred because universities were informed that industry was more interested in funding development and applied research, the deterioration of university laboratories, and university researchers discovering how to isolate and recombine segments of DNA (Allan, 1989).

The establishment of Research Applied to National Needs (RANN) within the NSF promoted applied research sponsorship, and authorized the NSF to support applied research at academic and non-profit institutions. Universities became more informed that

industry was more interested in supporting development than basic research.

While research interactions between industry and universities decreased during the 1970s, corporate donations and consulting by university faculty increased. Some institutions, such as Stanford, Harvard, and MIT, continued to aggressively promote and secure numerous partnerships with firms. The research center idea in 1973 led to increased relationships between universities and industry in the 1980s (Allan, 1989).

Research partnerships between universities and industry greatly increased at the end of the 1970s, and was highlighted with the Harvard University-Monsanto Corporation research partnership, which involved intellectual property rights for the company sponsoring research at the university (Allan, 1989). The 1980 Stevenson-Wydler Technology Innovation and the Bayh-Dole Patent and Trademark Amendments Acts created enormous impact on universities. The Acts allowed universities, non-profit organizations, and small businesses to retain intellectual property rights for inventions they developed with federal funding (Allan, 1989).

During the 1980s, universities and industries were informed of international competitiveness and a rapidly changing political environment, and the benefits of basic research were questioned. The benefits of engineering, and applied research became important discussions for university faculty, government, and industrial personnel.

In 1985, the National Science Foundation (NSF) initiated the Engineering Research Center (ERC) Program (Allan, 1989). The Centers were expected to conduct cross-disciplinary research that could lead to increasing world competitiveness of U.S. industry and improve the education of engineers at all levels.

Technology Transfer Legislative Acts

Major Legislative Acts in technology transfer have greatly increased and influenced university-industry partnerships. Congress was influenced by many years of negative trade balances, and decided to change U.S. Science and Technology policies. Congress recognized the need to use the research and technological resources of U.S. research universities and federal R&D laboratories by increasing the flow of knowledge and personnel to industry (Lee, 1995). The need for increased and faster technology transfer from universities to industry emerged as major legislation in 1980 when Congress passed three laws: the Bayh-Dole Act, the Stevenson-Wydler Technology Innovation Act, and the Cooperative Research Act (Lee, 1995).

The Bayh-Dole Act

Successful and increased university technology transfers resulted in an increase in health and economic benefits as the result of the Bayh-Dole Act. The Act provided an incentive for universities to market their innovations to industry, and for industry to assume high-risk investments for the leasing of university inventions (AUTM, 1998). Prior to passage of the Act, it was the policy of government agencies to take title to all inventions that were invented through the use of federal funds. The federal agencies holding title to the inventions were unsuccessful in transferring the technology of those inventions to industry. The bureaucracy that accompanied any attempt at leasing an innovation from the federal government was too great for many companies. As a

consequence, government agencies held patents on many inventions, but the technology represented by most of those inventions was never transferred to industry because no technology transfer policy existed for the government agencies (Bremer, 1993).

The Bayh-Dole Act created a patent policy for the federal agencies that funded research, and enabled small businesses, non-profit organizations, and universities, to retain the title of inventions made under federally funded research programs. The legislation was co-sponsored by Senators Birch Bayh of Indiana and Robert Dole of Kansas, and was enacted on December 12, 1980 (AUTM, 1998).

Prior to the Bayh-Dole Act, fewer than 250 patents were issued to universities each year, but in the past few years, U.S. universities have averaged more than 1,500 patents annually (AUTM, 1998). The Act allowed universities an option to receive title to inventions, and manage the marketing of their patents to industry (Bremer, 1993). The most important aspect of the Bayh-Dole was to provide universities with the title of the inventions, and this assisted in the expansion of university-industry relationships (Bremer, 1993).

Stevenson-Wydler Act

The Stevenson-Wydler Act in 1980 authorized federal laboratories to transfer technologies to industry, establish centers for industrial technology at universities and nonprofit institutions, and provided for the exchange of scientific and technical personnel among universities, industry, and the federal laboratories (Lee, 1995). The Stevenson-Wydler Act was designed to increase university-industry technology transfers.

Cooperative Research Act

In 1984, Congress increased the linkage of universities to private industry with the passage of the Cooperative Research Act. The legislation allowed universities and businesses to form technology transfer alliances without the fear of antitrust litigation (Lee and Gaertner, 1994). As a result, there was a growth of UIRCs (University-Industry Research Centers) that assisted in establishing relationships between universities and industry (Lee, 1995). The Act allowed patent holders to determine the length of an exclusive license up until the life of the patent, a minimum of seventeen years (Novis, 1993). Previously, exclusive licenses were good only for five years from the first commercial sale or eight years from the patent date, which ever is shorter. The intent of the Act was to reduce research and development costs. Historically, industry had been fearful of collaboration with federal and university basic research projects, but the Act helped to reduce the risk for industry to develop university and federal basic research projects (Novis, 1993).

Summary

The Bayh-Dole Act of 1980 was crucial in providing universities with the intellectual property rights from inventions that resulted from federally funded research projects. The Act provided incentives for faculty to invent, and for industry to assume less risk in establishing university-industry relationships for the leasing of university inventions.

The Conflicts of University-Industry Collaborations

Conflicts of interest may arise when the two cultures of academia and industry are attempting to concurrently fulfill their missions and objectives. As the federal levels of total research funding decrease, and U.S. technological competitiveness continues to be threatened, the benefits of university-industry partnerships have become more attractive. Some personnel in academia fear that as industry provides more funding for research and equipment for university laboratories, industry may attempt to influence the university curriculum.

Universities can study the organizational cultures of successful companies, but the industrial knowledge that they gain does not necessarily involve the best techniques and practices more suitable to the production of new innovations. Similar to business, universities have to admit the limits of their knowledge, and they can no longer assume that their research will produce a product that leads to a better society. In contrast, the academic culture may be a model for business, as industry adapts to a knowledge-based economy (Allan, 2000).

Some universities have been accused of conflicts of interest by a few sectors that are not on campus. The conflict develops when some sectors attempt to shield academic research from all outside influences, and keep universities in the ivory tower (Killoren, 1986). In contrast, some interests want universities to change academic curriculum to meet industrial needs, grant exclusive licensing and patent rights to industrial sponsors for university innovations.

Concurrently, universities cannot afford to distance themselves from the needs of other sectors because the institutions need the financial support from those sectors. They must combine the commercialization of their research with their missions of teaching and research, which is a difficult challenge for academic institutions because industry usually funds more applied research and less basic research (Sparks, 1985). Universities play a major role in pushing their technologies into the commercial sector where they benefit all of the sectors (Killoren, 1986).

Creating internal university policies to encourage researcher participation in industrial efforts is important because the social and organizational structures and environments of universities and corporations are often in conflict. The university's tradition of rewarding publication of basic research conflicts with the needs of industry to delay publications of university-industry research projects (Killoren, 1986).

Another controversy arises from the different missions and objectives of the two cultures. Industrial research is based on the need for specific industrial results to solve specific needs, and developed under secrecy from competitors, while university research is based on scientific inquiry, with open communications and public access to academic research results (Muir, 1990).

Profit from the results of academic research is another concern among some sectors. Some argue that profit diverts the attention of faculty from teaching and encourages the delay of research publications. They fear that university faculty with industrial support for research, consulting projects with industry, and as equity

participants, may compromise their responsibilities to the public. Some sectors argue that the goal of universities as centers of research, teaching, and service may be compromised by financial gain from their research, and that the research may favor short-term industrial interests (Muir, 1990).

Sparks reported that university research leans toward specialization for each institution in specific technological fields, with some research projects requiring large investments in equipment. New equipment and facilities attracts qualified academics and highly qualified research personnel, lowers industrial sponsorship costs, and allows the sharing of basic, applied, and development research (Sparks, 1985).

Most of the basic research in the U.S. is carried out in universities, and improving relationships between the two cultures ensures that industry uses the results of basic research in improving their competitive advantage. Concurrently, industry provides universities with direction for their research, which may eventually fulfill the needs of the public. Students and faculty generally adopt values of their environment, which is the university, and of the sponsors of their research, which has largely been the federal government (Sparks, 1985). Therefore, if students are to be employed by industry, the industrial culture can be introduced into the university environment. Concurrently, universities need to be willing to perform research that industry can use, and industry must be willing to use the research and technologies that are created at universities. Frequent and personal involvement between the university researcher and the industrial personnel is necessary in order to accommodate the university's research strength with industry's need for improved products (Sparks, 1985).

There must be flexibility in the relationship between industry and the university to work out problems concerning ownership of intellectual property, confidentiality of proprietary data, authorship for technical journals, and the selection of personnel who present the research and journal articles at the technical conferences. Additionally, universities have often been accused of not adhering to research schedules and of not recognizing the time constraints of business. In contrast, universities have reported that they are business-oriented, use strategic planning, and have adhered to timely projects (Sparks, 1985).

Research partnerships with universities have provided industry with processes and technologies, and have shortened industry's learning process within R&D companies. Industry has gained access to students and faculty, and has the opportunity to hire graduate students with experience in specific technologies. University-industry partnerships have allowed industry to maximize their educational efforts through scholarships, fellowships, internships, and sponsored research (Sparks, 1985).

Faculty Conflicts Caused by University-Industry Relationships

Center faculty recognize that an ERC is entrepreneurial-oriented, and that some of their colleagues outside of the Center, may have opposing opinions about the commercialization of their research conducted within the Center. A 1995 NSF Report by Lee reported faculty response to university technology transfer policies concerning university-industry partnerships. Lee's study revealed that U.S. faculty in the 1990s

believe they are more accepting than in the 1980s toward research policy awarding credits on research leading to patentable inventions, and approving applied industrial research as appropriate in the university. In addition, Lee reported that faculty strongly supported their university's active participation in regional economic development, and commercialization of university research. Similarly, the faculty endorsed institutional policy that promotes faculty consulting for private industry, but faculty members were reluctant to endorse policies designed to privatize academic research. While 56% refused to go along with involving their university in start-up assistance to new technology-based firms, nearly 74% refused to support their university becoming involved in business partnerships with private firms (Lee, 1995).

An additional finding in Lee's research was the perceived fear of close university-industry collaboration, which has shaped faculty attitudes toward technology transfer. Faculty fears from collaborations between university and industry were the major factors in the shaping of faculty attitudes toward university technology transfer. Faculty support for university technology transfer appeared to be connected to the assumption that close university-industry cooperation will improve the core values of the research university. For faculty with less fear of intrusion, the greater their support for technology transfer; and the greater the fear, the less support (Lee, 1995).

Faculty attitudes toward university technology transfer policies vary with several institutional and organizational characteristics. The differences in faculty responses to various institutional alternatives are a function of different academic disciplines (Lee, 1995). Faculty in the applied fields of chemical and electrical engineering, computer

science, and material science are much more supportive of various technology transfer policies than faculty in the basic or social sciences (Lee, 1995).

The pressure for external research grants plays an important role in the shaping of whether a faculty member is favorably or not favorably disposed to various technology transfer policies. Faculty members who feel pressured to seek external grants reported more favorable attitudes towards technology transfer policies. While R&D expenditures have but a moderate effect on faculty technology transfer attitudes, the rankings of institutional prestige reflected an unexpected pattern. The support for technology transfer was stronger among faculty in institutions ranked in the lower quartiles, and faculty ranked in the top quartile are less supportive of various technology transfer policies (Lee, 1995).

Summary

Conflict occurs when two different cultures with different missions and objectives attempt to form research partnerships. Some interests have fears that collaboration between universities and industry may cause industry to control academic curriculum, delay academic publications, and cater to industrial research that encompasses more applied and development research than basic research. The majority of faculty have fears about the collaborative effort between industry and universities, while industry has fears over intellectual property ownership issues, bureaucratic administrations, confidentiality of proprietary data, authorship of professional papers, and the ability of universities to adhere to deadlines. Universities and companies benefit, as well as the public when

universities produce quality basic research that can be advanced by industrial researchers for use in the market. Faculty that choose to be employed in an ERC understand that some of their colleagues may object to their performing of research that has been financed by industry, but the faculty eventually publish their research in the professional journals, and satisfy their academic and industrial colleagues.

Marketing from University Licensing Offices

The marketing of university inventions to industry mainly occurs from the institution's technology transfer licensing office. The most appropriate literature for the marketing of university inventions to industry has come from technology transfer associations. Though marketing of patented innovations seeking exclusive and non-exclusive licensees appears easier than the marketing of concepts or untested methods from ERCs, the methods used by university licensing officers (LO) and technology firms may be beneficial in identifying best practices for partnering ERCs with industry.

Universities usually rely on companies to lease and market the technologies that the universities create, and the large corporate firms are the most familiar with the marketing of university inventions. For those managing university technology offices, the challenge is how to identify companies as prospective licensees for university inventions. The management styles of university licensing offices vary with the number of personnel, their budgets, and marketing methods.

The case management style has often been practiced in many of the university licensing offices. In this system, one person has been responsible for all the actions

required for a particular case, from disclosure, patenting, and marketing the invention. This offers the advantage of centralizing information and coordination with all major aspects related to a particular intellectual property. The method has been practiced in large university licensing offices, but has required the talents of skilled licensing personnel with experience in processes from invention disclosure through commercialization (Allan, 2001). The depth of these processes usually leaves little time for marketing the invention. Few universities possess experienced marketing staff, and specifically, for marketing of their intellectual property to the corporate sector (Allan, 2001). The selection process for employment within university licensing offices has seldom addressed the marketing experience. Advertisements for university licensing positions have placed more emphasis on subject background, rather than marketing experience (Allan, 2001).

One marketing practice that has been used by many licensing offices has been the use of staff meetings with informal discussions of intellectual property cases by the licensing staff (Allan, 2001). At larger universities, the sharing of licensing cases and experiences has created an important internal knowledge base for licensing staff. Allan reported that the range of issues confronted by university licensing offices has expanded, and created challenges for university licensing officers (Allan, 2001).

Hsu and Bernstein's 1997 study focused on university inventions, where the licensing office had filed for a patent, but the technologies remained unlicensed. Interviews were conducted with the inventor, licensee, the licensing officer, and venture capitalists. The biotechnology and super conducting sectors were most attracted to the

technologies generated by the universities. The authors were seeking if university technology licensing offices were committed to their technologies and how successful were TLOs in getting technologies licensed (Hsu and Bernstein, 1997).

The participants in the study reported two motivations for their interest in licensing university inventions. First, is the strength of patent protection, and second is the fact that technologies created in universities are important sources of competitive advantage for their companies. Hue and Bernstein's results compare with the research of Levin who found that the power of patents varies among industries, and that patents were rated as most powerful in the drug-related pharmaceutical and biotechnology sectors (Hsu and Bernstein, 1997).

If the university holds a patent for an invention, the granting of an exclusive license to the company leasing the invention provides the company protection from competitors. The offering of an exclusive license may induce a company to invest the resources needed to bring the invention to market. Numerous university faculty have university licensing personnel file for their patents each year. More than 25% of the science and engineers in the academic sector, who submitted at least one patent application within 1990-95, reported that the patents granted to them resulted in at least one commercialized product or process that was licensed. Biotechnology and pharmaceutical sectors received the most patent activity in universities, but in industry, patent activity was more broadly distributed across technological areas (Morgan, 2001).

Hsu and Bernstein found that the most important factors contributing to the successful licensing of university inventions were the effort of the entrepreneurs who

leased the inventions, the value of the technologies, and financing issues. The university technologies not licensed were the result of insufficient proof of concept, and in the embryonic stage of development, which were not commercially attractive. The authors reported that having a prototype was extremely important for the non-biotechnology sector. The external sources of marketing failure were inaccurate information, industrial organizational failures, disrupting technologies, and embryonic technologies (Hsu and Bernstein, 1997). The difficulty in predicting royalty income for early stage technologies has discouraged many companies from entering into licensing inventions with universities (Thursby et al., 2001).

There are several reasons for the biotechnology market in university licensing. Many biotech companies have one-decision-maker with the authority to invest in new technologies, and venture capitalists seem fairly patient with the longer development time associated with biotechnology. Venture capitalists demanded broader platform technologies before investing in a start-up, and beginning biotechnology companies are becoming the licensors of technologies. The biotechnology industry originated from universities and academic faculty, and many of the founders of biotechnology firms came from academia. The small biotechnology start-ups and universities appear to have similar cultures. Biological discoveries and the need for university technologies in the biotechnology industry are driving academic research and commercialization with more than 50% of the biotechnology products coming from discoveries in university laboratories (Hsu and Bernstein, 1997).

The licensees of biotechnology usually demand proof of concept at an earlier

stage of development than in other sectors. Industry devotes enormous financing for R&D, and part of the funds are spent developing technologies created in universities. Therefore, it may be more beneficial for biotechnology companies to maintain in-house R&D personnel, and license earlier stage technologies from universities.

Thursby, Jensen, and Thursby reported the stage of development at the time the university personnel negotiated the license with the company. The stage of development percentages were “proof of concept but no prototype 45%, prototype available but only lab scale 37%, some animal data available 26.7%, manufacturing feasibility known 15.3%, ready for practical or commercial use 12.3%, and some clinical data available 9.5% (Thursby et al., 2001 p.62).”

Many inventions from university research are disclosed at a very early stage of development, and require additional development before they can be introduced into the market (Thursby, 2001; Colyvas, 2002). In the study (2001) of 62 research universities, Thursby, Jensen, and Thursby reported that 50% of the university inventions were licensed at the proof of concept stage of development (Thursby et al., 2001). In the Hue and Bernstein study (1997), one biotechnology was not licensed because the licensees demanded proof of concept.

Due to the early stage of university inventions, Thursby, Jensen, and Thursby reported that 71% of licensed inventions required inventor assistance to move the technology to the market. The companies establish a relationship with faculty with specific specializations before they license an early stage technology from a university. The licensing of early stage inventions requires different marketing methods, including

the selection processes for finding prospective licensees, and the parameters of the licensing agreements between universities and industry. This study reported that small companies were more likely to license early stage technologies, and large companies were more likely to license late stage inventions (Thursby et al., 2001).

Patent protection at the time of licensing can be a measure of the embryonic nature of technologies, since patents are often applied for a technology that has an opportunity for commercial success. Thursby, Jensen, and Thursby reported that university inventions were not always protected by a patent when the technologies were licensed by the companies. The authors reported that 48% of the respondents claimed that there was patent protection some times, 28% claimed rarely, 13% often, and 12% of the respondents reported almost always (Thursby et al., 2001).

Many university licensing offices outsource their legal functions, while the marketing functions are performed by licensing personnel. Marketing functions for university inventions are variable, with some universities performing minimal marketing, and only listing university technologies on the institution's web site. Large and small universities usually market their intellectual properties through web-based services, university home pages, and through the professional licensing associations Web sites (Allan, 2001).

There has been increased competition from many companies, including corporate out-licensing, consultants, fee-based companies, and Web-based services, but there has been no increase in marketing methods for many university licensing offices. A small university licensing office requires enormous effort from the licensing personnel in order

to successfully license an invention. The small institution lacks the prestige of a major research university to license their technologies, and they lack the personnel or financial resources to aggressively license their technologies (Allan, 2001).

Larson and Wigand's report to the NSF in 1987 on technology transfer between Arizona State University and the micro-electronics industry in Phoenix, revealed that industrial and university researchers used different strategies to make contact with one another. Industrial researchers relied on personal knowledge and experience for identifying prospective research partners, and attended presentations made by university faculty at conferences or read researcher's publications. University researchers relied on their academic colleagues to recommend prospective industrial partners (Larson and Wigand, 1987).

Industrial researchers usually initiated the contact with university faculty, but when industry did not initiate contact, industrial personnel were working jointly with university colleagues in research projects (Williams and Gibson, 1990). The greatest benefit of cooperative research for the majority of the industrial researchers was access to university faculty and students. In contrast, the greatest benefits for the university faculty of collaborative research with industrial personnel was access to industrial funding, equipment, and industrial knowledge. Other benefits that attracted university faculty to industrial personnel were improved communications with industry, increased knowledge of a subject, increased faculty awareness of industrial concerns, and opportunities for student employment with industry (Williams and Gibson, 1990).

Hsu and Bernstein reported that financing issues were a key factor of licensing

success for start-up companies. University equity and licensing fees policies were determining factors to whether a start-up entrepreneur licensed or declined to license a technology. Most start-ups stressed the importance of minimizing high up-front licensing fees (Hsu and Bernstein, 1997). The licenses executed at 62 research universities provided payment options that included inventor assistance, and provided options for the up-front licensing fees. The licensing agreements usually included small up-front licensing fees, sponsored research, and equity positions in the licensing company (Thursby et al., 2001). University licensing offices that have policies and procedures that assist the faculty and include them in the development process are more successful. Some licensing offices assist the faculty inventor in locating financial resources, and providing connections to research parks and incubators (Colwell, 2002).

In the Hue and Bernstein study, the factors of licensing success were the granting of exclusive licenses for university inventions. The threat of direct competition was usually the reason for the prospective licensee to decline to license if an exclusive was not provided. Therefore, Hue and Bernstein reported that the granting of exclusive licenses has the potential to increase the success rate of licensing (Hsu and Bernstein, 1997). In the Thursby, Jensen, and Thursby study (2001), 74% of the respondents reported that when the licensing included sponsored research, the option to negotiate exclusive licenses almost always existed (Thursby et al., 2001).

In contrast, Colyvas, Crow, Gelijns, Mazzolini, Nelsom, Rosenberg, and Samprat reported that a non-licensing company made investments to develop products that were based on the invention. The company reported that if their research were successful, the

company would receive a patent for the development research, and therefore, would not need protection from their competitors. The case provided a different method for successful commercialization, where a patent and exclusive licensing of the university invention was not necessary (Colyvas, et al, 2002).

A study of industry by Cohen et al (1998) sought the most important benefits received by companies from university research. For most companies, the most cited benefits were publications, scientific communication, and consulting, while few companies reported licensing of university inventions as an important benefit (Cohen et al, 1998).

With a network of technology companies in close geographic proximity to a support infrastructure for start-ups, entrepreneurs may license more university inventions. Boston's Route 128 and Silicon Valley are examples that have numerous technology firms with many qualified professionals, infrastructure, materials, and funding in close proximity (Hsu and Bernstein, 1997). Cooke (2002) reported that when there is a large group of qualified personnel performing biotechnology research in a centralized area, there are generally more industrial interactions with biotechnology personnel (Cooke, 2002). In contrast, there are research centers that have researchers performing quality research with industrial support, but the research centers may not stimulate economic growth within the immediate area.

The majority of licensing failures within the Hsu and Bernstein study (1997) were caused by failing to build relationships with existing companies. The internal reasons for university marketing failures were inaccurate incentives for licensing officers, personnel

unable to specialize, and licensing staff holding on to technologies. The Thursby, Jensen, and Thursby study (2001) reported the methods used for the marketing of inventions in university licensing offices. The majority of the methods were personal contacts 75%, followed by inventor contacts with 58.3%, direct mailing and fax 52.5%, web site 37.5%, meetings 20.8%, and trade shows 18.8%. The authors reported that some of the university licensing offices, which listed personal contacts, were most likely referring to the personal contacts of faculty (Thursby et al., 2001).

In a study of companies that license in university technologies, Thursby and Thursby reported that 46% of the respondents claimed that personal contacts between R&D industrial personnel and university faculty were extremely important in identifying technologies to license. The authors reported that faculty were the main contributors for leads in marketing university inventions to industry (Thursby and Thursby, 2000). The Jansen and Dillon (1999) study reported that 56% of the primary leads for licensing inventions came from faculty (Jansen and Dillon, 1999).

When companies have acquired the knowledge regarding a research project, they are more likely to consider licensing the technologies generated by the research. Companies gain that knowledge by entering into sponsored research agreements with a university or through personal relationships with the inventors. In such cases, as long as conflict of interest and intellectual property issues have been well communicated in advance, the licensing process usually proceeds smoothly (Hsu and Bernstein, 1997).

Two strategies within the Hsu and Bernstein (1997) study, networking with current licensees and companies, and adopting customer feedback methods, helped in

successfully transferring technologies to companies. Non-licensing respondents suggested several methods for attracting prospective companies. Some of the methods are establishing and maintaining personal contacts in industry, visiting companies, extending invitations to industrial personnel to visit the university research facilities, and frequent personal follow-ups with targeted companies. Though a particular technology may not be licensed immediately, the licensing officers' efforts helped to establish numerous industrial contacts and informed many industrial personnel of the university's inventions (Hsu and Bernstein, 1997).

An unsuccessful licensing strategy was marketing through the mail to prospective companies by casting a large untargeted net. The sending of literature and letters may reach the right industrial personnel, but the information usually becomes buried by more important company projects (Hsu and Bernstein, 1997). Marketing research and networking results in targeting of prospective companies and an understanding of the market. Large companies are well-focused on specific industrial needs, and have many internal R&D projects, and are not able to consider all university inventions (Hsu and Bernstein, 1997).

The licensing of university inventions has not always resulted in positive results from the perspective of the companies. The Thursby and Thursby study of industrial licensing executives, reported that 66% of the companies had not licensed inventions from universities (Thursby and Thursby, 2000). The executives claimed that many university research projects are in an early stage of development. Other reasons for not licensing were university ownership issues, restrictive delay of publication policies, and

the necessity of faculty cooperation for the development of the technology (Thursby and Thursby, 2000).

A major obstacle to recruiting industrial members at an ERC at the University of Minnesota, was the concern that the funding of the research would support administrative bureaucracies rather than research. In reality, the university provided the funds to cover Center personnel, and the industrial membership fees were all directed toward the support of research (Evans, 1993).

Hsu and Bernstein reported that there two conditions in which the licensing officer may be successful in the licensing of inventions. The conditions are when entrepreneurs take on the responsibility for funding and developing technologies, and when the licensee has a pre-existing relationship with the inventor (Hsu and Bernstein, 1997). The success or failure to license university inventions may depend upon the willingness of faculty to take part in the project (Siegel et al, 2001). A university licensing office can create conditions that improve licensing successes by sponsoring technology shows for inventors, venture capitalists, and entrepreneurs. The office could gather leads from existing licensees and previous investors, and ask the inventor for licensing leads (Hsu and Bernstein, 1997).

Most university licensing personnel have recognized that the inventors are the most important sources of industrial contacts and licensing leads. Licensing personnel can improve their licensing success by asking inventors to increase their industrial contacts by attending more conferences, and sharing industrial leads with their academic colleagues. Other methods for improving licensing successes are asking former students

and researchers that are employed with companies, personnel interested in start-ups, and other faculty within the university with patents and inventions. Hsu and Bernstein recommended the hiring of interns from business and law schools for marketing research projects and patent searches (Hsu and Bernstein, 1997).

Hsu and Bernstein reported that networking strategies for licensing personnel could include more face-to-face interactions with prospective licensees by visiting companies, and meeting with technology acquisition and R&D personnel, and inviting them to the university. Licensing personnel could be more selective in targeting their prospective companies. Hsu and Bernstein reported that inventions that do not match a prospect's industrial needs should not be forced on to the client. Trying to unload an unproven technology on a prospective company may ruin a relationship that could flourish with the correct technology. Multiple marketing efforts may be necessary for companies recovering from a slow economy, or after a technical advance has improved the attractiveness of the technology (Hsu and Bernstein 1997).

Hsu and Bernstein have recommended that there should be greater university support for more risk-taking, with aggressive promotion of university licensing. The ripening of technologies that are too embryonic for companies to initially license can be accomplished by seeking gap funding from private technology developers, and the increase of technological alliances with other universities and federal agencies can increase licensing leads (Hsu and Bernstein, 1997).

Thursby and Thursby identified personal contacts between R&D and university personnel as the most important source of university technologies, followed by journal

publications, patent searches, and presentations at conferences. The least important sources were marketing efforts by universities and canvassing of universities for technologies. Companies do not license-in technologies from universities because of the culture of university research. Numerous executives reported that university policies regarding delay of publications and refusals to transfer IP ownership were issues that caused their companies to not license from the university (Thursby and Thursby, 2000). Universities could be more flexible with their intellectual property rights with industry, and less bureaucratic. In contrast, universities complain that companies do not understand the university's culture or policies (Siegel, et al. 1999).

The Thursby, Jensen, and Thursby (2001) and Thursby and Thursby (2000) results, compared with the Jansen and Dillon (1999) results with inventors/faculty being the primary source of licensing leads. Jansen and Dillon's study (1999) reported 56% of the licenses were a result of leads from the inventor, and 19% were the result of marketing by the university licensing personnel (Jansen and Dillon, 1999). Jansen and Dillon reported the primary leads by license, but Thursby and Thursby (2000) reported the importance of many sources in identifying university technologies to license-in.

Thursby and Thursby sought the importance of journal publications, patent searches, presentations at professional meetings, and canvassing of university technologies. Journal publications and canvassing universities for technologies are important for large companies with abundant licensing personnel. Patent searches are more important for companies that possess only a few licenses (Thursby and Thursby, 2000).

The average level of sponsored research for the companies that did not license-in from universities was 75% higher than for companies who have licensed-in from universities (Thursby and Thursby, 2000). Industrial respondents claimed the importance of personal contacts with university researchers, but the unimportance of university technology transfer office marketing efforts. The industry executives claimed that additional reasons for not licensing-in technologies from universities are the high licensing fees, and the difficulties attributed to academic arrogance toward industry, indifference towards smaller companies, and the bureaucratic policies of universities (Thursby and Thursby, 2000).

Marketing strategies that include research, and the targeting of specific companies are usually successful in finding licensees for university inventions. If a company declines to license a technology, the inventor has the option to use the industrial feedback to either modify the technology to make it more licensable, or to develop a more market-oriented technology. Inventors should listen to the needs of the prospective industrial licensees, before abandoning their inventions (Muir, 1997).

Companies make their decisions for selecting new inventions to move to commercial products by examining many technologies and their fit in the market. The institutions holding the inventions should examine the market conditions for the invention, and the capabilities of their prospective licensees to move the invention to a commercial success before entering into a license (Muir, 1997).

Another study reported that R&D, manufacturing, distribution, sales, and

marketing were indicators that can be evaluated for comparative purposes. The importance of these indicators varies by industry, for instance, with R&D important for early stage technologies and sales and marketing are more important for companies that possess a large customer base, and for products with complicated technical understanding that require many interactions with the customer (Muir, 1997).

The stage of development of an invention is an important consideration when targeting a company as a prospective licensee. The technology may be in the concept stage, or researchers may be in the process of reducing it to practice, or it may be reduced to practice and be demonstrating utility. The first two stages represent partially developed technologies that are embryonic and high-risk. Inventions in the third stage have advanced towards being ready for the market. The stages of development provide alternatives for high-risk investors and for conservative investors (Muir, 1997).

Each company has individual industrial needs, and may be interested in technologies that are in various stages of development. The high-risk companies are more interested in embryonic inventions, but the embryonic inventions usually require a long-term commitment. Companies that are controlled directly by their owners, small companies, and start-ups tend to be the most receptive to high-risk technologies (Muir, 1997).

Technology licensing personnel should target companies that possess excellent manufacturing and distribution facilities, and have the capabilities to move the invention to the market. The companies selected for licensing of the invention should have produced products that are similar to the new technology, and possess the capabilities to

make the invention a success. Some of the companies that are prospective licensees may be large corporations with multiple subsidiaries with many product lines, and many departments may be interested with the invention (Muir, 1997).

The industrial departments that seek university inventions are legal, R&D, engineering, marketing, and technology acquisition departments. Successful marketing of the technology requires the technology licensing personnel to work patiently with each company, and through numerous corporate organizational structures and departmental contacts. Licensing personnel have to identify the correct industrial personnel within the company who can be a champion, and convince upper management that the technology can be profitable for the company (Muir, 1997).

The amount of marketing for an invention depends on the resources of the licensing office. Successful licensing of inventions requires a targeted search of primary and secondary sources for prospective licensees. The industrial directories, and the Internet are secondary sources, and some possess classification schemes under which companies are grouped by the products they produce (Muir, 1997).

Massachusetts Institute of Technology (MIT) Technology Transfer Program has been successful because of the university's strong applied research, and the institution's on-going relationship with industry (Levine, 1989). The licensing office has accumulated a large number of patents, and has launched aggressive marketing campaigns of MIT inventions to prospective companies through a number of marketing methods. The MIT marketing methods include a large database of 30,000 companies, conducting sponsored research projects with industry, communicating with industrial liaison personnel, and

through targeted mailings (Levine, 1989).

Other universities have used the identical methods to be successful in the licensing of their technologies. The University of Utah has been successful in the licensing of small inventions that bring in less than $100,000 per year in royalties. With a database of over 2,000 companies, the university has earned over $500,000 in royalties per year, which was been generated primarily, through mailings to numerous companies. Other technology licensing offices have developed formal business plans (Ozda, 1990).

Technology transfer exists between Duke University, the University of North Carolina, and North Carolina State University, and has led to the creation of the Triangle Universities Licensing Consortium (TULCO). TULCO identifies prospective industrial sponsors, and negotiates with industry for sponsored research projects performed by faculty members from the universities, but with the final agreements negotiated by each university. Technology transfer conferences are a method for universities to exhibit their inventions, as well as Science and Technology exhibits, which are held with the intentions of attracting prospective high technology companies, and venture capitalists (Novis, 1993).

Marketing of Engineering Research Centers

Engineering Research Centers (ERC) have been very successful in attracting and providing many benefits to industry. In 1995-96 there were 694 industrial memberships in 20 ERCs, with an average of 35 companies per ERC (NSF, 1997b). Of these companies, 31% were small businesses, 17% were medium sized companies, and 52%

were large companies. The NSF reported in 2000, that 600 inventions, 300 patents, and 1400 software licenses have come from 15 years of ERC research (NSF, 2004).

In 1994, the National Science Foundation (NSF) initiated a study of key interactions between ERCs and industry. The study did not single out the biotechnology or wireless integrated micro-systems sectors, but grouped all the sectors in the results. The purpose of the ERC-Industry study was to examine the patterns of interaction that emerged between ERCs and industry, and which interactions were the most useful and brought companies the greatest benefits (NSF, 1997b).

The study reported that the ERCs vary in their strategic plans for industrial recruitment. Only a few Centers had no active recruiting or promotion, and responded only to inquiries from industry. Most Centers target companies, establish membership goals, conduct market research to identify prospective companies, and customize their recruitment strategies for each prospect (NSF, 1997b).

The marketing techniques used for recruitment of industrial members consisted of mailing of literature, newsletters, and brochures, visits to industrial sites by Center Directors and faculty, visits to the ERC by industrial personnel, exhibits at targeted industrial conferences, participation at technical society conferences, publication of technical papers, participation in industrial research consortia, web site home pages, informational videotapes, letters to prospective industrial sponsors identified through leads, and workshops at the Centers (NSF, 1997b).

The study reported that the amount of value from a Center membership is directly related to a company's length and amount of involvement with the ERC. Major benefits

are usually, not received in the first year or two of a company's membership, but members receive a wide range of benefits that are improving their competitiveness and knowledge. Of these benefits, the most important are in the areas of access to new ideas, technologies, access to Center faculty, networking with other industrial members, access to ERC equipment and facilities, and employing Center graduates (NSF, 1997b). The longer a company has been a member of a Center, the more likely the company will continue to support the Center (NSF, 1997b).

The hiring of Center graduates was reported as the top benefit of Center membership by companies who employed former ERC students. In addition, a 1982 NSF study of university-industry relationships reported the access to Center students as the main reason companies joined industrial programs (NSF, 1982). Two-thirds of the companies reported gains in competitiveness as a result of ERC membership, and the majority of the respondents reported that their ERC membership had influenced their company's research agenda (NSF, 1997b).

A key marketing method for Centers is to inform industrial members that a long-term relationship is important for the partnership to be beneficial. When Center personnel inform the industrial members to the numerous activities involved at the Center, the more the members will benefit from their membership. When industrial members delay becoming involved in the Center, and take no active role in the Center, the benefits are delayed and threaten the longevity of the membership (NSF, 1997b).

Three factors are strongly related to positive outcomes for companies from their memberships with an ERC. These factors are the existence of a champion for the Center

within the company, the willingness of industrial personnel to accept Center research and results, and support from upper management within the company for the Center membership. The largest barriers that prevent companies from Center membership are due to company priorities that prevent the company from taking advantage of Center involvement. Other major barriers to Center membership are a result of the differences in missions, values, goals, and timelines between universities and industry (NSF, 1997b).

The appeal of a new Center has been very effective in attracting industrial members. As Centers mature, maintaining the industrial memberships requires Center personnel to provide more time for the industrial members as they become more demanding for results of their membership (NSF, 1997 b). New Centers have to establish the vision and infrastructure for effective Center-industry partnerships, a technology transfer program, and a system for tracking Center-industry interactions (NSF,1997b).

Making cold calls and mailing literature to prospective industrial members are unsuccessful methods for recruitment. The successful methods for recruiting industrial members included continuous correspondence with numerous industrial personnel, Center faculty visiting the companies, and industrial personnel visiting the Center. Center personnel target specific companies based on their experiences with other members, the industry, and their technologies (NSF, 1997b).

In a 1988 study of the first ERC industrial members, the participants indicated that they became informed of the ERCs by different methods. The most common method was through previous knowledge of the Center faculty or faculty research. About 66% of the respondents in the study had previous knowledge of the faculty, 62% had previous

knowledge of research at the university, and 45% had a prior relationship with the Center's Research Director before the Center was established. Approximately, 14% of the respondents were contacted by Center personnel and without previously knowing them, and 10% had heard about the ERC at an annual industrial meeting. Industrial members with previous university research experience were most likely to become members of an ERC (NSF, 1988).

The industrial participants of the study reported that the quality and type of research are the reasons their companies joined the ERCs. The industrial participants rated type and quality of research as very important reasons for participating in an ERC, and reported that cross-disciplinary and joint research as moderately important reasons for joining the ERC. The majority of industrial respondents claimed that the research matched the company interests, and the quality of research and researchers were extremely important reasons for joining an ERC. In addition, a majority of the participants rated access to research results and research which interests the company, as extremely to very important reasons for joining an ERC (NSF, 1988).

For new Centers with no research results, it was best to describe the Center research and the possibilities for sponsored research projects. This method has been effective with companies that have been involved with other ERCs. Industrial personnel have suggested that having an Industrial Liaison Officer was necessary for maintaining and improving the Center-industry partnerships (NSF, 1997b).

Industrial members have employed many of the ERC graduates. Numerous companies have reported that ERC graduates that are trained in systems, are more

capable at problem solving than their non-ERC graduates. The graduates can integrate knowledge across many fields, work in teams, understand industrial needs, and address problems from an engineering systems perspective. Many ERC faculty and their industrial members have reported that ERC graduates are the best method of technology transfer (NSF, 1997b). Industrial members have provided industrial experience for ERC faculty and students by hosting faculty sabbaticals, student internships, and on-site ERC seminars. Industrial members visit the Center for workshops and seminars, and interact with the faculty and graduate students (NSF, 1997b).

The Industrial R&D Culture

An understanding of the industrial R&D environment is important to establish Center-industry relationships. Universities and industry have different cultures, objectives, and missions, and academic and industrial researchers have different needs. Many academic researchers are engaged in research projects, and share their university knowledge and technologies with industry. Faculty interactions with companies are usually restricted to a particular company that requires specific researcher expertise (Rahm, 1995).

University-industry communication and linkage methods are of two types, informal and formal, and the informal are dominant in differentiating industry researchers from university researchers. Industrial researchers are usually more aggressive than academic researchers in contacting another company representative or faculty (Rahm, 1995).

Informal communications between university and industry researchers are established through technical meetings, conferences, emails, and telephone conversations, and are extremely important for technology transfer to be successful (NAE, 1997). Informal contacts promote discussion between the two parties, and the interactions progress into more formal types of joint cooperation with research grants or contracts (NAE, 1997).

Consulting by faculty has been an important channel of technology transfer. Most science and engineering faculty spend approximately 20% of their time on outside activities, which may include consulting for industry (NAE, 1997). Many faculty view consulting for industry as important opportunities for gaining industrial knowledge, income, securing funding for research, and creating support for their graduate students. Consulting by faculty with multi-year contracts has been an effective method for creating long-term relationships with industrial sponsors.

Another successful method of university-industry technology transfer has been the exchange of research faculty with industry (NAE, 1997). Research universities often engage in temporary exchange of research personnel with private industry for collaborative research projects (NAE, 1997).

The major interest of university-industry interactions has been new graduates, and a specific area of research that will benefit the company (Fusfeld, 1999). To accomplish their company objectives, industry may provide grants or research fellowships to a faculty member working in a specific research specialty, who often uses the money to

support graduate students. The specific research project, while of interest to the company, is usually not the main reason for providing the grant. The industrial intention of the grant is to gain access to graduate students trained in an area of interest that benefits the company interests. A second intention for industrial funding is to maintain a relationship with specific faculty in a selected area of research to gain industrial knowledge.

Research projects are mainly initiated by academic researchers, but preceded by many meetings and discussions with the industrial sponsor. Approximately two-thirds of all such research cooperation has been followed by a previous consulting arrangement between the researcher and the industrial sponsor (Peters, 1982). When research grants are not larger than $35,000, the industrial sponsor will usually accept the patent policy of the university (Fusfeld, 1999).

The most important research interaction between the university and industry is when the company has a strong interest in the results and has provided the grant. When the company has a high interest in the research, the funding level will be greater with additional financial support for graduate students. Funding for the research project is usually in the amounts of $75,000 to $200,000, and patents are important. The company is usually seeking research advances for their developments, and need patent protection from their competitors (Fusfeld, 1999).

When university enters into a research partnership with a company, and grants an exclusive patent right, it limits opportunities with other companies. The area of patent coverage must be well-defined, and apply only to a specific research program. A company cannot obtain intellectual property rights to a broad field of application by

supporting a narrow research program. Some companies believe that the greater the level of industrial financing, the broader the range of exclusivity. Many academic institutions have strong patent policies, and do not give away their patents, but some companies will not sponsor research unless they have exclusive licensing or ownership of the intellectual properties (IP).

Many universities are very aggressive in seeking industrial funding for their research support. The academic researcher usually develops a research program, and targets a few companies that may be interested in a specific type of research. The information is accumulated from the university researcher through attendance at conferences, informal discussions with industrial personnel, and consulting for industry. Fusfeld has reported that industrial personnel are available for communications concerning sponsored research that can assist their companies, but the promotion and selling of the research projects are mainly initiated and conducted by academic researchers (Fusfeld, 1999)

Establishing relationships with universities strengthens the R&D of a company, but they should be an extension of the R&D activities of the company. Fusfeld (1999) has reported that a company can use a university research program to add to an internal industrial research program, but not as a replacement for the industrial program. Fusfeld (1999) claims that the difference in the expected results and goals of universities and industry are the reasons that companies have not assumed the initiative in seeking university fellowships, grants, or university research programs. In contrast, he claims that it is changing because university research programs have become part of the strategic

planning for some corporations. A slower economy has caused corporate R&D to downsize and outsource, and industry has become more assertive in seeking quality academic research programs (Fusfeld, 1999).

The marketing of intellectual properties within the private sector can create enormous increases in revenue when companies learn how to market their intellectual properties (Davis and Harrison, 2001). Most of the focus has been on patent mining, and the marketing of the patented invention has become problematic for some institutions. The process involves identifying customers for the invention, contacting the correct personnel, targeting the right companies, informing them of the invention, and closing the lease of the invention. The most time consuming part of marketing is spent in finding the prospective customer, and negotiating to complete the research contract (Davis and Harrison, 2001).

Companies gather business and technical information about their competitors for the prediction of future markets, products, and technologies, and should implement an information system for their own intellectual properties, and for their competitors (Davis and Harrison, 2001). The competitor's information can be utilized to improve the company's efforts to develop new technologies. With numerous inventors and start-up companies, technology competitors have become more difficult to detect, and not identifying them can eventually be harmful for the company (Davis and Harrison, 2001).

While the standard methods for marketing are product, price, place, and promotion, the methods for marketing of technologies demand modification (Mohr, 2001). Research findings have reported that increased marketing is required for

breakthrough products than for other products (Song, 1996).

Barriers to R&D marketing collaboration have been caused by the corporate culture of high-tech companies that prefer engineering expertise rather than marketing expertise (Mohr, 2001). A dominant engineering culture has resulted in the majority of upper management executives who are expected to learn the functions of business as they progress in the company. Increasing R&D and marketing interactions with company personnel has allowed products to become successfully introduced into the market (Mohr, 2001.

Summary

Though few research articles were found that addressed, specifically, the best methods for building and maintaining ERC-industry partnerships, relevant technology transfer articles from journals were used in the literature review. With continued membership growth in technology transfer associations, an increase in technology transfer offices on university campuses, increased downsizing and outsourcing of industrial R&D, and an increase in university-industry sponsored research, more literature on innovative methods for the marketing of technology from universities is occurring in this rapidly growing field. During the course of the study, new articles on technology transfer have continued to appear in technology transfer publications.

CHAPTER 3

METHODOLOGY

The methodologies used to identify best practices in building and maintaining ERC- industry research partnerships are described in this chapter. The data for the comparative case studies were collected at two NSF Engineering Research Centers; the Center for Biofilm Engineering (CBE) at Montana State University (MSU), and the University of Michigan (UM) Center for Wireless Integrated Microsystems (WIMS). The chapter includes nine sections with (1) the purpose of the case study; (2) the research questions; (3) the research design; (4) the participants and data sources; (5) the data collection instruments; (6) the data collection process; (7) the data analysis strategy; (8) a summary of the proposed methodology.

Purpose of the Case Study

The purpose of the comparative case study is to describe the ERC-industry partnership development of two successful Engineering Research Centers (ERCs). The study is important because the successful practices and marketing methods that enabled one of the ERC's to become self-sustaining upon graduating from eleven years of NSF funding, and the other Center to enlist and maintain many industrial members will be described. The comparative case study is additionally important because it provides insight to marketing methods and practices that have been used by successful Centers in

becoming self-sustaining. If ERCs do not become successful upon graduating from NSF funding, the research entity is dissolved. The majority of the NSF graduating Engineering Research Centers (ERC) have been dissolved because they were not able to become self-sustaining (Costerton, 2002).

Research Questions

The main question answered in the comparative case study is what are the best practices that resulted in building and maintaining Center-industry partnerships? A second question answered in the study is what practices did not assist in building and maintaining Center-industry partnerships?

The Research Design

The research design was a comparative case study of two NSF Engineering Research Centers (ERCs). The Centers are the Center for Biofilm Engineering (CBE) at Montana State University (MSU), and the University of Michigan (UM) Center for Wireless Integrated Microsystems (WIMS). Best practices from each Center that were successful and practices that failed were compared through the use of three data sources; (1) face-to-face interviews with the Center Directors (CD), Center Industrial Liaison Officers (ILO), Center faculty, and university technology Licensing Officers (LO) who are responsible for Center intellectual properties (IP); (2) a thirteen question survey handed out to industrial members attending Summer and Fall 2003 Technical Advisory Conference (TAC) meetings at the Centers; and (3) a description of the best practices for

building ERC-industry partnerships from NSF-ERC site visit documents from the two research Centers.

The collected data was managed by the researcher through separation of the data according to (1) Centers; (2) separation of interview categories by sub-categories for Center Directors (CD), Industrial Liaison Officers (ILO), Center faculty, and university technology licensing officers; (3) separation into survey categories for industrial members for each Center; (4) the separation of NSF-ERC site visit documents into categories for each Center. In addition, color-coding was used to match similar and contrasting opinions, and similar opinions matching multiple sub-categories.

The data analysis for the comparative case study was conducted using the pattern-matching method. For example, the opinions of one Center faculty may match a similar pattern of Center faculty interviewed at a different ERC. Additionally, the opinions of technology transfer personnel and Center Directors may greatly contrast and warrant placement into a contrasting pattern. Some of the patterns were sufficiently contrasting to enable the findings to be interpreted in the answering of the research questions (Yin, 1994).

Participants and Data Sources

In order to ensure the validity of the comparative case study several forms of data collection were conducted (Yin, 1989). In addition, because qualitative researchers rely heavily on verbal description, the main instrument of data collection, interpretation, and written explanation was the researcher (Gay, 2000).

For the comparative case study of best practices for building and maintaining university-industry partnerships, the researcher (1) collected data using on-site interviews of Center Directors, Industrial Liaison Officers, Center faculty, and university technology transfer personnel; (2) distributed, collected, and analyzed open-ended surveys of industrial members attending the Centers' Summer and Fall 2003 Technical Advisory Conference (TAC) meetings; and (3) collected and analyzed NSF-ERC site visit documents from the two Centers.

The Engineering Research Centers

Two NSF Engineering Research Centers were purposively chosen from the National Science Foundation's (NSF) Engineering Research Center (ERC) Program, which consists of approximately 30 Engineering Research Centers, because of their success in acquiring numerous industrial members. Gay states, " because samples need to be small, and because many potential participants are unwilling to undergo the demands of participation, sampling in qualitative research is almost always purposive. That is, the experience and insight of the researcher is used to select a sample"(Gay, 2000p.139). In addition, Gay states, "that the primary focus in qualitative research is on identifying participants who can provide information about the particular topic and setting being studied, not participants who necessarily represent some larger population (Gay, 2000 p.139)."

The researcher associated with the research setting through completion of a one-year internship, and was granted continual association with the Center for Biofilm Engineering (CBE) at Montana State University (MSU), Bozeman. This enabled the

researcher to observe and obtain information that was used to select the two NSF Engineering Research Centers described in this study.

The Center for Biofilm Engineering (CBE) at MSU has graduated from NSF funding, and has became self-sustaining due to a large industrial membership. The University of Michigan's (UM) ERC for Wireless Integrated Microsystems (WIMS) is in the fourth year of its NSF funding, and has created and maintained many industrial memberships. The Center for Biofilm Engineering (CBE) has 23 industrial members, and the Center for Wireless Integrated Microsystems (WIMS) has 19 industrial members.

Interview Participants

Interviews were conducted with Center Directors (CDs), Industrial Liaison Officers (ILOs), university Licensing Officers (LOs), and Center faculty who are project leaders at Montana State University (MSU), Center for Biofilm Engineering (CBE). Similar personnel at the University of Michigan (UM) ERC for Wireless Integrated Microsystems (WIMS) were interviewed. In addition, a survey was distributed to industrial members attending a Technical Advisory Conference in July 2003, and a Industrial Advisory Conference in October 2003.

The Center Directors were chosen because they possess the historical administration and marketing knowledge of the Center. They are required by NSF to market the Center to their university administration, private industrial sectors, and to federal agencies. The industrial liaison officers were chosen because of their strong job responsibilities for the marketing of the Center to industry, and because they are the central communications liaison for the linkage of university personnel with industrial

members. Center faculty who are project leaders were chosen because they usually possess the most knowledge of the research, inventions, and personnel within their research program that has drawn the interests of private industry to the Center. They have worked professionally with the inventors who have created the technologies that industry has found attractive.

Additionally, interviews were conducted with university technology licensing personnel from the two institutions who are responsible for Centers' intellectual properties. University technology transfer licensing personnel are responsible for the marketing and licensing of university inventions to industry. University licensing personnel that are directly responsible for the licensing of Center inventions were chosen for the study because of their responsibilities for marketing of university and Center inventions to industry.

Survey Participants

Industrial members were chosen for the study because they are the majority who consume Center research, lease Center inventions, and they are a large financial resource in assisting a Center to become self-sustaining. Usually, industrial members that participate in the semi-annual Technical Advisory Conference (TAC) meetings at the Centers are Heads of R&D from one of their company's business units if they are from a large corporation, or they may be a CEO from a small private company. The industrial members that attend the meetings are usually personnel that possess the historical research knowledge of the Center-industry partnership, and they have experience from having been contacted by many research personnel and Center faculty from the ERCs.

Industrial members were asked to complete an open-ended survey while in attendance at Summer and Fall 2003 Center Technical Advisory Conference (TAC) meetings. The questions were open-ended, and were provided by the researcher with input from several industrial members in a piloted survey. Industrial members were asked for their opinions for the best practices for building and maintaining Center-industry partnerships.

Center Documents

NSF-ERC site visit documents from Montana State University (MSU) Center for Biofilm Engineering (ERC), and the University of Michigan (UM) Center for WIMS were collected and analyzed for best methods for improving and maintaining Center-industry partnerships. NSF site visit documents were chosen because NSF site visits are mandatory for the continuation of NSF funding, and the documents contained historical marketing methods that were used for the building and maintaining of industrial Center memberships. The documents contained the Center's marketing methods for building Center-industry partnerships, and the NSF site review committee’s recommendations for improving Center-industry partnerships. The reports were analyzed for best practices for improving Center-industry partnerships, and for inefficient methods that were unsuccessful in recruiting and maintaining industrial members to the Center.

The Instruments

Yin reported that interviews, surveys, and historical documents are an essential source of case study information (Yin, 1989). Therefore, for the comparative case study

of the two ERCs, the standard interviews and survey questions that were developed were based on questions that are frequently described in NSF guidelines for the Engineering Research Center Program which pertain to building and maintaining industrial constituency. The questions asked of the participants in the face-to-face interviews were similar to those asked in the industrial member survey. This allowed for confirmation of data between the face-to-face interviews and the survey responses. In addition, the NSF-ERC site visit documents included marketing methods, and suggestions from the NSF review committee that could improve and maintain Center-industrial partnerships.

The Interview Protocol

The interview instruments used for the comparative case study included interviews of Center Directors, Industrial Liaison Officers, Center faculty who are leaders of research projects, and university technology licensing personnel who are responsible for Center intellectual properties. The purpose of the use of interviewing as an instrument was to allow the researcher to enter into the participants' perspective (Patton, 2002). Since knowledge of the participants' perspective was important for the case studies and because there were less interview participants than survey participants, the researcher gained an additional perspective from the case studies from conducting the face-to-face interviews.

The interviewees were asked to describe the best methods for building and maintaining an industrial membership to their centers. Additionally, the interviewees were asked to describe methods that failed to enlist industrial members at their Centers.

Interviews of Center Directors (CDs) elicited methods they used for attracting ERCs to industry, methods for selecting prospective industrial members, and the Center Director's articulation of Center vision to industry and university administrators. Additionally, the CDs were asked to describe the number of Center patents, company spin-offs, technologies transferred, the exclusive licensing policies, best marketing methods for building and maintaining industrial members, and the number of alliances with universities and federal agencies.

Interviews of Center Industrial Liaison Officers (ILOs) revealed the methods they used for building and maintaining industrial partnerships, methods that were unsuccessful, systems used for the tracking of interactions between Center and industrial personnel, the process for identifying prospective members, and the sources of leads for prospective members. Additionally, the interviewees were asked to describe the patent, technology transfer, and exclusive licensing activities, the Center marketing plan for recruitment of industrial members, marketing practices that were unsuccessful, and practices that caused members to not renew their Center memberships.

Interviews of Center faculty revealed the initiator of the first contact between Center and industrial personnel, if prior consulting and research assisted in the enlistment of members, and if the Center ILO asks the Center faculty for industrial leads. Additionally, the interviewees were asked to describe their marketing methods of the Center to industry, the best methods that build ERC-industry partnerships, the unsuccessful methods for enlisting prospective industrial members, and the contribution of Center students in the building and maintaining of Center-industry partnerships.

The University Licensing Officers (LO) interviews elicited the sources of industrial leads for licensing of Center technologies, university policies that enhanced the licensing of Center inventions, and the best marketing methods for Center inventions. Additionally, the interviewees were asked to describe the effects of exclusivity on licensing results, and the funding methods they used for ripening technologies to make them more attractive to industry.

The Survey

The survey was selected as an instrument because it was used most often in case studies in the researcher's literature review. The survey was handed out to industrial members attending Summer and Fall 2003 Technical Advisory Conference (TAC) and Industrial Advisory Board (IAB) meetings at the ERCs. Respondents were asked to describe how ERC-industry relationships were initiated, who initiated them, how and why the relationships progress or disintegrate, how industries seek out Engineering Research Centers, and the benefits that industrial members are seeking in their relationships with ERCs.

Industrial members were asked to describe who initiated the first contact between Center and industrial personnel, methods used for first contact, industrial reasons for joining and continuing as members of the Center, and provide suggestions to better market the Center to industry. Additionally, the respondents were asked to describe industrial methods used for seeking university research, members satisfaction of Center membership, university inhibitors that prevent partnerships with ERCs, and the most and least valued benefits of ERC-industrial partnerships.

A pilot study was conducted to improve the survey questions, and was distributed to three industrial members in the comparative case study. The pilot project was conducted at the Technical Advisory Conference (TAC) meeting at the Center for Biofilm Engineering (CBE), July 2001. Industrial members attending the conference were asked for feedback, in the form of suggestions for improvement to the questions within the survey instrument. Some of their suggestions were used in the industrial survey.

Center Historical Documents

The NSF-ERC site visit documents were selected as an instrument because the documents contained NSF site committee reviews, and Center marketing methods for building and maintaining industrial memberships. The documents contain marketing methods used by Center personnel, and methods that are recommended by the site committee for attracting and maintaining industrial members.

Data Collection Process

Interview Collection

The researcher used multiple data collection techniques known as triangulation (Yin, 1994). The triangulation of the data permitted the verification and validation of the data. As such, the three data collection sources provided the researcher with a form of triangulation in addressing the research question. All sought to answer the primary research question asked in this study. The researcher used face-to-face interviews, an industrial survey, and historical NSF-ERC site visit documents.

For the interview collection process, a letter was sent to the participants of the comparative case study prior to the interview. The letter was sent to Center Directors (CDs), Industrial Liaison Officers (ILOs), Center faculty, and university licensing officers (LOs), and included a list of the questions. The mailing additionally, explained the purpose of the case study, and the reason the researcher was requesting the interview. The participants were contacted through telephone and email to arrange an appropriate interview time.

The interviews were conducted within the participant's office at the university where the participants were employed. The Center Directors (CDs), Industrial Liaison Officers (ILOs), Center faculty, and university licensing officers (LOs) were interviewed and recorded with two cassette tape recorders. There were no objections from the participants to being recorded, and the additional tape recorder was used to remedy any potential technical recording problem, and prevent having to re-schedule an interview. The interviews were completed in November 2003 at the University of Michigan (UM) Center for Wireless Integrated Microsystems (WIMS), and at the Center for Biofilm Engineering (CBE), Montana State University, in June 2003.

Survey Collection

The researcher distributed and collected the industrial member surveys at the Center for Biofilm Engineering (CBE), Montana State University (MSU), Technical Advisory Conference (TAC) in July, 2003. The Industrial Liaison Officer (ILO) for the Center informed the participants at the conference the purpose of the survey, the

confidentiality of the survey, and the significance of the survey to the industrial members. The surveys were handed out to all the industrial members at the meetings. The Industrial Liaison Officer (ILO) asked the participants to return their survey to the researcher at the conclusion of the day, or if they needed more time, the participants could complete the survey by the end of the conference, and return the completed survey to the ILO. Each survey was coded in order to assist in accurately tabulating the data. Surveys given to the industrial participants that were associated with the CBE, were coded with the letter C, and the surveys distributed to the Center for WIMS participants were coded with the letter W.

NSF-ERC Document Collection

Permission to review the historical NSF-ERC site visit documents at the CBE was granted by Dr. Bill Costerton, the past Director of the Center for Biofilm Engineering. In addition, Dr. Bill Costerton, the CD, and Paul Sturman, the ILO, at the CBE, were the researcher's references in gaining permission to review NSF-ERC documents, and collect data from the UM Center for WIMS. The researcher received approval from the UM, Center for WIMS, Center Director, Dr. Kenneth Wise, in August 2003, and collected the data at the Center for WIMS in November 2003.

The researcher collected NSF-ERC site visit documents that indicated the Center marketing methods for building and maintaining an industrial constituency. Some of the documents contained NSF site visit committee reviews of the marketing methods of the Center, and any deficiencies or areas that needed improvement. The documents reflected input from NSF staff for marketing methods to be implemented by the Center. The

documents additionally, contained any industrial member concerns about the Center.

Data Management

While collecting the data, the researcher developed a manageable coding scheme, and maintained a database that included an interview journal and a historical file of the case studies. The large amount of data collected and maintained was managed by the researcher through the placement of the data into categories and subcategories, within numerous color-coded folders. Initially, the categories included; (1) Centers; (2) interview categories with sub-categories for Center Directors (CD), Industrial Liaison Officers (ILO), Center faculty, and University Technology Licensing Officers (LO); (3) question categories with sub-categories for each question; (4) separation into survey categories for industrial members for each Center, and sub-categories by questions; (5) the separation of NSF site visit documents into categories for each Center. In addition, color-coding was used to pattern-match similar and contrasting opinions of the participants of the case studies, which assisted the researcher in identifying patterns and themes.

Data Analysis Strategy

The data analysis consisted of three concurrent activities: data reduction, data display, and conclusion drawing (Best and Kahn, 1993). The greatest challenge for the researcher was managing large amounts of data, reducing the massive volume of information, identifying significant patterns, and constructing a method for interpreting the collected data. The data analysis involved identifying, coding, categorizing,

classifying, and labeling the primary patterns found in the data.

The researcher analyzed the content of the interviews, the surveys of the industrial members, and the NSF site visit documents to search out patterns and themes from the opinions of the participants of the case studies. Interview and survey data was organized by grouping answers together across specific respondents. For example, Center Directors (CDs) interviews were analyzed and compared for each question.

NSF site visit data were organized by Center, successful Center marketing methods, unsuccessful methods, and NSF marketing recommendations. Color-coding was used to simplify the process with numerous color-coded folders to enable the researcher to associate the opinions of the participants into similar, contrasting, and multiple patterns and themes.

Summary

The purpose of the comparative case study was to describe the ERC-industry partnership development of two ERCs. The main question that was addressed in the study is what are the best methods for building and maintaining ERC-Industry partnerships? A second question that was addressed is what methods did not assist in building and maintaining ERC-Industry partnerships?

The research design was a comparative case study of NSF-ERCs. The ERCs studied were the Center for Biofilm Engineering (CBE) at Montana State University (MSU), and the University of Michigan (UM) Center for Wireless Integrated MicroSystems (WIMS). The comparative case study was used to compare the best

practices from each Center that were successful and practices that were unsuccessful. Using three instruments; face-to-face interviews with Center Directors (CD), Industrial Liaison Officers (ILO), Center faculty, and university Licensing Officers (LO); an industrial survey from industrial members; and NSF-ERC site visit documents the research questions were addressed.

The participants and data sources of the comparative case study included the collecting data through interviews of CDs, ILOs, Center faculty, and university LOs, surveys of industrial members attending Technical Advisory Conferences, and the NSF-ERC site visit documents.

In the following chapter, the results of the data analysis are presented. As such, the research question addressed in the study is answered. In Chapter Five, these findings will be interpreted in terms of their implications for the practice of building and maintaining Center-industry research partnerships.

CHAPTER 4

RESULTS OF THE CASE STUDIES

Through the use of a three-part methodology, the data of the comparative case study are presented to answer the research questions. The three-part methodology consisted of (1) answering a series of questions using face-to-face interviews with NSF Center Directors, Industrial Liaison Officers, Center faculty, and university technology transfer personnel responsible for Center intellectual properties, (2) a survey completed by industrial associate members attending the July and October 2003 Technical Advisory Conferences at the Centers, and (3) the review of NSF-ERC site visit documents, which reflect methods pertinent to the building and maintaining of Center-industry research partnerships.

In this chapter, the results of the comparative case study include the combined results from the interviews with respondents from the Center for Biofilm Engineering at Montana State University, Bozeman, and from the University of Michigan Engineering Research Center for Wireless Integrated MicroSystems. The chapter begins with the results from the responses of the participants, the Center Faculty, Center Director, Industrial Liaison Officer, and university technology transfer personnel, followed by the survey results from the industrial associate members, and concludes with the results from the data from the NSF-ERC documents. Within each section, the results are presented in a numerical order of the questions asked of the participants and for the survey. The results are presented in three main sections, which pertain to the three parts of the

methodology selected to answer the research questions.

Face-to-Face Interviews - Center Faculty

The results of face-to-face interview are presented in the numerical order of the questions presented to the participants. The sequence starts with the answers proposed to the Center Faculty, followed by the Industrial Liaison Officer, the Center Director, and concludes with the results of the interviews with the university technology transfer personnel. In total, eight thrust leaders were interviewed from a questionnaire that contained seven questions. A thrust leader is the lead researcher in one of the Center's major research areas.

Question One

Have you done previous consulting for any of the companies that are current or past industrial associate members of your center?

Four of the faculty completed research projects and consulting before and after the members joined the Center. One faculty member performed research projects for a company before the company joined the Center, but no consulting. One faculty completed research projects and consulting only after the companies joined the Center. One faculty performed consulting for a company prior to the formation of the Center, and the company is currently a member. One faculty member worked for a company and performed consulting for them, but the company had joined the ERC before the faculty member came to work at the Center. He reports the relationship helped company personnel perceive continual value in being a member of the Center.

Question Two

Who initiated the first contact in the relationship with the companies and yourself?

Five faculty suggested that industry had contacted them for research projects or consulting work. Two of the faculty reported that the Center Director initiated the first contact with industry and the faculty were contacted later by industry. One of the faculty was contacted by industry because he had conducted previous research projects for the company before it joined as a member. The company was very familiar with the expertise of the faculty member. One faculty member was asked to make a presentation at the industrial site after the CD gave a presentation. The company became more interested in Center research after hearing the faculty presentation and eventually asking the faculty to do a research project.

There are differences in the opinions of the faculty of how industry became aware and eventually contacted them. One faculty member reported that the Internet, and the Center for Biofilm Engineering (CBE) web site, and publications were instrumental in industry contacting the faculty for their expertise in a certain area. One faculty reported that going to the companies and talking to them is extremely valuable.

> The faculty member stated, “the Center Director may be invited to give a presentation at the industrial site, and with further interest, a faculty member makes a presentation at the industrial site that is more closely aligned to the company’s needs. With more interest, industrial personnel are invited to attend one of the Technical Advisory Conference (TAC) meetings at the Center. Many of the companies just want to sponsor research projects, and do not want to join the Center.”

One faculty member reported that he had completed research projects for industry and federal agencies that were past members. The faculty member reported that because industry was familiar with the researcher, the company renewed the relationship, began a new research project, and became a Center member. One faculty suggested that it is different with each company, and reported that companies who are current members usually contact the thrust leader in the ERC projects.

For non-members, the companies find the faculty through literature or from referrals with other companies. The faculty member reported that there exists a difference between small and large companies in their involvement with the faculty, and becoming members of the Center. The small companies ask many questions, but usually, cannot afford site visits, Center conferences, or the membership fees for joining the Centers. In contrast, the larger companies know what they are looking for, and ask very precise questions. One faculty reported that the Center Director and ILO are usually the initial contacts, and that he has been the initial lead a few times. The contacts were a result of attending conferences and through meetings at the company sites.

One faculty member reported that companies usually contact him after he makes a presentation at a conference. Many company representatives attend conferences, listen to faculty present their research, read their publications, and eventually they contact the Center faculty.

> This faculty member stated, “I may run into industrial personnel at a conference that can benefit from their company’s involvement with the ERC. I try to market the Center to the company, and sometimes invite the personnel to visit our Center, and participate in our Industrial Advisory Board meetings prior to becoming members.”

One faculty indicated that the ERC mainly initiates the contacts with industry, but the Center has had several companies that have contacted the faculty because they were interested in faculty research, and not necessarily interested in joining the ERC. He suggested that some industrial personnel are interested in technologies that the Center faculty have developed. Additionally, many industrial personnel request information about faculty research and a few ask the faculty to consult for them.

When industry contacted the Center, the faculty member claimed he would describe Center research and explain to the industrial representative that the ERC is not necessarily interested in working in a narrow research area that may be of interest to the company. He further explained that there are a large number of projects and activities within the Center that may be of a peripheral interest to the company.

> The faculty member stated, "many industrial personnel know that certain faculty members are experts in a particular field, and when a project comes up for a company, they may ask faculty to consult for them. It is not necessarily that consulting resulted in the company joining the Center, because many of these companies know the faculty from various research conferences and publications. The interactions, numerous connections, and familiarity probably would have resulted in the companies joining the ERC, whether consulting was there or not. Consulting does help because the faculty become more familiar with the industrial personnel, and maintaining the relationship over a long period was critical in the company joining the Center."

Question Three

Does the Industrial Liaison Officer (ILO) at your Center ask you for industrial leads for prospective new members?

All of the respondents answered yes, and claimed that there was no formal

process for the exchange of industrial leads to the ILO at the ERC. The faculty reported there has been a continuing informal process where Center faculty provide prospective industrial leads to the ILO after returning from a conference, visiting a company, or performing research for a company.

One faculty member collects business cards at conferences, and passes them on to the Industrial Liaison Officer (ILO) when he returns to the Center. One faculty member reported that his colleagues pass on the information to the ILO. When a faculty member is working for a company, and the company representative expresses any interest, the faculty will pass information to the ILO. The ILO will invite the prospective member to the next Technical Advisory Conference (TAC) at the Center. The prospective members usually come to the TAC if they are from large companies. Many of the small companies usually do not join the Center.

One faculty member stated, “the ILO does not ask me for leads when I return from a conference or company visit, but it is assumed that when I return from visiting a Center, the ILO and I will meet to determine the level of interest of the prospective member. Additionally, the ILO asks me if there are any industrial personnel that the faculty would like to invite to the TAC meeting.”

One faculty member indicated that the thrust leaders meet every week with the ILO and Center Director to inform staff of the status for each company, and it is the best time to pass along the industrial contacts to the ILO. One faculty member reported that he and the ILO pass on information routinely to each other. The faculty member claims that industrial contacts usually occur because the faculty or his students have made a

presentation at a conference.

Question Four

How do you as Center faculty, market the Center to industry?

One faculty member reported that the Center trademark, which is posted on his slides, is a marketing tool because they are seen when he presents his publications at conferences. In addition, he reported that faculty web sites are important for Center faculty to attract industrial personnel to the Center after industrial representatives have attended faculty presentations at a conference or after visiting a company site.

One faculty member reported that the ERC markets methodologies to government and industry and because many of the Center methodologies have been given freely to industry and government agencies, the royalty-free technologies have become a marketing tool for the Center. One faculty member promotes the Center through personal communications at every conference when he presents his professional papers. The faculty member reported that he always mentions that the Center has an industrial program. Although many companies may fund Center research projects, not all companies that sponsor Center research join the ERC. One faculty claims that making presentations about Center research and doing consulting are marketing methods for the Center. The faculty member does not look at consulting as a means for creating revenue, but as a method for marketing the Center. He provides information about the workshops and the types of facilities available to the prospective members at his presentations. When faculty are invited to the industrial site, there is greater exposure when presenting to numerous industrial personnel than making a presentation to one industrial

representative. The faculty member claims he always mentions the Center at every conference, provides the Center web site, and invites his audience to visit the ERC web site.

One faculty suggested that when industrial personnel initiate the contact, the companies are usually seeking a faculty member with a specific expertise for their industrial needs. Web sites and publications in journals are two places where personnel are first informed of the Center. After the company has identified the focus area for research, faculty are contacted and invited to the company. The faculty usually first promote their research as it relates to the company interest, describe the research depth and breadth of the Center, and address the Center commitment to education and technology transfer.

One faculty member reported that when industrial personnel approach him at conferences or he sees a presentation from an industrial researcher that is close to the research conducted at the ERC, he will attempt to discuss with the industrial representative research interests that may mutually benefit both parties. The faculty member claims that he is occasionally invited to visit the companies, and provide presentations, and in return, the faculty member invites the industrial personnel to attend one of the Industrial Advisory Board (IAB) meetings at the ERC.

The Center for WIMS invites industrial researchers to speak at a Seminar Series at the university where the ERC is located. While at the university, the industrial guest meets all the thrust leaders at the Center, and they discuss their research with the industrial researcher.

In addition, the faculty member is Head of the Master of Engineering Program that grew out of the Center for WIMS. One of the goals of the program is to reach out to industrial practitioners and career people who want to take a refresher course or obtain a Masters degree. The ERC advertises the program with electronic mailings and flyers. The Program is three years old and has a few students who were in industry and have come back to school for an advanced degree.

One faculty member reported that his publications, presentations at international conferences, and numerous presentations at company sites are all helpful in marketing the Center. One faculty claims that publications, going to industrial sites alone or with faculty and students, and making presentations of their latest research are marketing tools. The faculty member claims that the Industrial Speaker Seminar Series, where industrial personnel are invited to speak within the College of Engineering, is another marketing tool for advertising the Center.

Question Five

What are the best methods that build ERC-industry partnerships?

One faculty reported that the Center must have a quality product to promote. The Center has to be recognized as a specialist in a particular field. With a quality product, it is easier to target specific companies and demonstrate to key industrial personnel that the Center has industrial relevance. As the relationship begins to build, the Center becomes part of the industrial budget because it contains visibility, credibility, and revenue from industry.

The faculty member reported that to maintain industrial interest the Center finds a method to address the basis of a research problem. Center personnel have to be careful when addressing a specific company problem, otherwise industrial members will object if the ERC tries to solve a company problem with group membership funds. Center faculty attempt to find a solution that is a problem for a block of companies that are members of the Center and if an industrial member wants to have a specific problem solved they must pay for it through sponsored research. An industrial representative may make a claim that the Center has used money generated by ERC industrial memberships to solve a single company problem for one of the members which has created a difficult challenge for the Center in balancing group interests.

A faculty member indicated that the ERC must have an ILO who communicates with the industrial members all the time. He reported that the Center for WIMS has such an ILO. One faculty reported a similar pattern with solving industrial research problems. The faculty member reported that when Center personnel collaborated with industrial members in solving a problem that the industrial group had presented to the Center, it kept the industrial members around for numerous years. The faculty member reported that to get a collaborative project going is important in maintaining memberships, because the Center will lose industrial members if the industrial personnel do not become active. Center personnel must have the willingness to answer all phone calls and email questions, travel to company sites, and provide numerous presentations for the industrial personnel. Typically, the companies invite the Center Director or one of the Center faculty to the company. The Center personnel put on a presentation, discuss the ERC

facilities and the Center research, and answer industrial personnel questions. As their interest builds, industrial personnel investigate the ERC web page and Center literature, attempt to obtain the depth of the Center research, and eventually, the companies send a few industrial personnel to the Center.

At the ERC, the Center faculty inform the industrial personnel of Center research, provide a tour of the Center facilities, have numerous meetings with the industrial representatives, and discuss issues of interest for the company. Occasionally, the Center personnel give workshops at the industrial site, and inform the industrial personnel of new research methods. The companies send their personnel to a workshop at the ERC and to the Center Technical Advisory Conference (TAC) meetings and hopefully, the companies join the Center.

Occasionally, companies lose interest in the Center and become disappointed if the Center did not come up with a discovery in a specific area. If a company was disappointed in their membership, the Center faculty assist the company by providing them additional consulting time to help the company make the discovery they are seeking, and maintain their industrial membership. The Center faculty attempt to discover the specific problem the company is experiencing, which is a difficult thing to do with some of the companies because the majority of them do not share their company problems openly due to competition.

Center faculty attempt to be very informative and specific about Center capabilities but try to elicit from the companies specific details that will keep them as members of the Center. Personnel changes within the company, loss of a champion,

internal politics, finances within the company, a transfer out of the country, or retirement of key personnel may cause a company to leave the Center. It is very difficult to get industrial personnel to inform Center faculty why their companies are losing interest in the Center and to inform faculty their reasons. The extra time that Center faculty provide in assisting industrial personnel in solving their industrial issues can be worthwhile if the company continues as a member or funds a sponsored research project with the Center.

One faculty member reported that communications with the industrial personnel is key to maintaining Center memberships. The faculty member claims that the industrial members assist in marketing the Center to other companies. The faculty member stated, "we have had many successful contacts throughout the years who subsequently joined or became active in the Center. The Center has to be alert to any marketing opportunity to inform industrial personnel about the Center and what the center can accomplish for a company. With increased promotion of the Center, through the use of different formats and targeting methods, the greater the increase in memberships."

The faculty member stated, "Center personnel must being willing to listen to the industrial members. The Center maintains the industrial members by listening to them, and developing innovations with faculty research." The faculty member suggested that Center personnel need to deliver that message to the industrial members in the context they want to hear, identify company interests, and target them for Center information. The industrial members need to inform Center personnel if their membership is beneficial or helpful to their company. Industrial members trust that the ERC membership will provide knowledge that will help them in a financially beneficial way. Occasionally, the

industrial members use the Center to develop or test their products. The faculty member reported that for the companies that have stayed with the Center, their industrial representatives were able to clearly convince upper management that the Center investment was rewarding financially. Hopefully, the industrial members are able to say to their upper management, “because of what we learned at the TAC meetings and from the research they have conducted at the Center, the company has been able to make several key decisions that ended favorably for the company. In addition, since benefits have exceeded the costs, the company should maintain their membership to the Center.”

The faculty member reported that good students, faculty, facilities, and receiving quality research that can be integrated into the company are the benefits that help members maintain their industrial membership at the ERC. The faculty member reported that losing a champion makes it difficult to retain the industrial member. The faculty member reported that occasionally there has been more than one champion within the company, and when one industrial employee left the company, the other employee took over as the champion. Ultimately, an industrial representative in the company has to decide that the ERC industrial membership is a great benefit for the company. The industrial personnel favoring membership in the ERC has to sell the Center membership to upper management every year. If the promotion of the benefits of the membership does not occur each year, the companies are not going to stay with the Center. The Center does not expect companies to stay with the Center forever. The faculty member claims that the Center has been very fortunate to have many long-standing members.

> One faculty member stated, “It is like any other relationship. The Center-industry relationships take persistence and dedication. The

> main methods that keep the industrial companies involved are the semi-annual TAC meetings, having the members visit the Center, and keeping them engaged. Center personnel need to make the industrial members feel like they have a voice, and insure that Center research is on the cutting edge. If you are not on the cutting edge, it is not economically feasible for a company to stay involved with the Center."

The faculty member reported that the center for Biofilm Engineering (CBE) has been trying different methods to retain industrial members. For instance, when a company's upper management needs more justification for maintaining membership with the Center, the faculty will ask the R&D personnel to give the Center a project that Center faculty can solve for the company. The successful solution can be passed to upper management to convince them that the Center is a worthwhile investment. The faculty member reported that the Center Director travels frequently to present his publications at conferences and his activities greatly increase the Center's visibility and success.

One faculty member reported that there is more involvement with the companies when working on a joint research project because it involves the parties on a different level of interaction with increased collaboration and exchange of scientific knowledge. The faculty member stated, "when the industrial members bring the Center faculty a research question, the faculty help the industrial personnel to focus the research question, and select the best methods to find the solution. When the two parties work together on a research project, the dual interactions enlighten Center faculty to the important issues of industrial members, and the Center faculty can better understand the constraints that the company encounters in the work environment." The faculty becomes educated to many industrial issues such as, industrial advertising and environmental compatibility. The

faculty member reported that the Center has more long-lasting relationships with companies that engage with the Center in collaborative research projects. The Center faculty are constantly asking the industrial members about their company's special interests, reasons for specific research areas, and how the company can achieve their goals. It is an informal process that can occur over lunch, with Center faculty attempting to discover how to integrate the company interests with faculty research. Most of the time, if the companies are interested in doing a research project, they will drop an idea, and inquire what would be involved to make the project occur.

The faculty reported that communication is important, such as, keeping the web site current, going to conferences, publishing in journals, and going to the company site for presentations to industrial personnel. It involves personal contact by visiting and meeting industrial personnel, participating in workshops, inviting industrial personnel to the Center, and to the Center TAC meetings. There are numerous interactions and communications that occur before a company joins a Center.

The faculty reported that the industrial members maintain membership in the Center because of continuing interactions, their belief in the benefits of Center membership, and an industrial champion who promotes the Center to their upper management. The faculty member additionally reported, "it becomes especially hard when the champion gets promoted, retires, or is transferred. The industrial membership can be in jeopardy, unless the Center can find another company employee who can maintain the same level of enthusiasm for the Center. There has to be somebody in the company who is excited about Center research to justify the membership fee on an

annual basis to upper management."

A Center for WIMS faculty member claims that the Industrial Advisory Board (IAB) meetings have been very helpful for maintaining continuity. Industrial representatives are able to attend presentations from numerous Center faculty at the meetings. Industrial members are informed of the best research and how they can achieve continuity from the commercial quality laboratories. The University of Michigan Center for WIMS, Michigan State University, and Michigan Tech have been sending students to industry for many years, and established a long-term relationship between the universities and industry. There are cases of past students that have been employed by industry, and eventually, their companies joined the Center. The Center research did not begin when the Center was established because industry has benefited from previous research at the Center. The Center has directed and coordinated numerous researchers toward a common goal, which has increased the Center's exposure to industry.

> One faculty member stated, "most of the research that the Center performs has been long term, but companies want Center research to remedy their immediate problems. In some cases, the partners find common ground where some of the research at the Center is of interest to industry.
>
> Center faculty inform industry of the benefits of membership to the Center. For example, what works and what does not work, or the company should look at specific areas they have not researched or research they should abandon."
>
> "Most of the time, Center engineers and technicians know their counterparts, which are the technical personnel in industry. For example, I have known an industrial employee for 20 years, and we attend the same conferences. Center faculty must establish relationships with the right personnel, find the right things to research, establish their strong research, insure that industry visits the faculty and faculty visits industry, and the Center personnel

must perform all of these things extremely well."

The faculty member reported that with the current economy, companies have to justify their research funding. He claimed that the NSF should assist companies by convincing their upper management that "the ERCs are the jewels of the NSF, and they have some of the best students, educational programs, and some of the best research in the world."

The faculty member articulated an analogy of an industrial member joining a Center as to someone joining a health club. He stated, "If you do not attend or take advantage of any of the amenities that the club offers, the member will wonder if they should continue to be a member. But if you go and receive the slightest benefit you will maintain your membership in the club. Even though the benefit ends up being less in value in the amount of money spent for being a member, you tend to still maintain that membership because maybe next year you will receive more benefits than last year."

The faculty member reported that the industrial members join for the intellectual property, the technology, students, and to license the inventions. Usually, companies join to have an advantage over their competitors, to be informed of the latest inventions, or because an industrial competitor has joined the Center. He claims that some of the industrial members join because they were pressured by a faculty member, who may be their lifelong friend, and the industrial personnel feels obligated to join the Center.

Question Six

What works the least in building Center partnerships with industry?

One faculty member claims that not calling the industrial members will cause

them to quickly lose interest in the Center. Most of the faculty reported that mass mailings and cold calls do not work in marketing and attracting industrial members to their Center.

One faculty member associates the poor economy for reasons for companies leaving a Center. Additionally, the faculty claims that Center personnel must not assume that prospective industrial members will find the Center on their own initiative. He reported that the Center has to perform market research and identify where industrial personnel have an interest. For instance, the Center use to have several oil companies as members, and currently, there are more medical companies than oil companies as members. The faculty member reported that sending literature with no follow-up failed in building partnerships. Sending a large amount of information and literature about the Center was not adequate, because prospective members need to see the relevance associated with their particular industrial needs.

One faculty member at the Center for WIMS stated, “any marketing of the Center that does not have personal interaction is not going to work.” The faculty reported that mass mailings and cold calls did not work, and that a time factor may hinder companies from joining a Center. He explained, “if I meet an industrial representative at a conference and invite them to the next IAB meeting, it could be six months before the meeting, and before the I see the industrial personnel. After the industrial personnel attend the IAB meeting, they return to their company, make their decision; initiate the process for joining the Center, and that process could take another year. It takes time and work for the Center faculty as well as for the industrial personnel to see the value in each

of their interactions. It involves an educational process for both parties, and that time constant may hinder membership to the Center."

One faculty member from the University of Michigan reported, that "if the Center can get a company to join, and then neglect having numerous interactions with them, they do not continue their membership." Additionally, he claims that "sending Center literature in the mail, and asking prospective companies to be members is not personal interaction. The Center staff need to have the personal face-to-face interactions with industrial personnel, and the industrial representatives must be informed and see the benefits of being an industrial member of the Center."

Question Seven

Do you feel your students have contributed to industrial members joining or maintaining their membership in the Center?

One faculty member reported that the students market the Center by disseminating information about the Center, while they are employed by industry. One faculty member reported that most of his graduate students are eventually employed by industry. He indicated that two of his former students are currently working for a company that is not a member of the Center, but the company has entered into a sponsored research agreement with the Center. The former students attend the TAC meetings as industrial representatives. The faculty member further reported that one of his former students is employed at a federal agency, which is not a current member of the ERC, but the former student's supervisor use to work for a company that is a current member of the Center. The faculty member claims that an excellent opportunity currently

exists to enlist another federal agency to join the Center, or an employee of the federal agency may become a champion for the Center. The students are not the primary reason for members joining the Center, but they are a benefit of membership of the Center. The students can bring expertise quickly into their company when employed.

One faculty member claims that many of her students are employed by industry or consulting companies. Some of the students have joined companies that were not members, and the former students have assisted in getting their company to join the Center. The faculty member is reluctant to allow any company to delay research publication for a graduate student, because it is part of the student's educational goals. For a faculty member, there may be a delay of publication negotiated from six months to a year, and there have been a few exceptions where it has been longer. One faculty member claims that delays of publication are not good for his graduate students, and the companies may object if the students want to publish their research in a scholarly journal.

A faculty member at the Center for Wireless Integrated MicroSystems (WIMS) reported that industry wants students who have been trained in the Center because of their talents, developments, and familiarity with the technology. The special training received at the Center for WIMS sets the University of Michigan apart from other universities that might be specialized in a different field. One faculty member indicated that one of the main interests of the industrial members have been the students that are hired from the Centers. Former students of the University of Michigan have become Center champions within the companies.

Center Directors

The Center Director for the Center for Biofilm Engineering was previously a Director of a research Center at the University of Calgary. When he accepted employment as CD of the CBE at Montana State University, six of the Canadian companies that were members of the Canadian research Center transferred to the Center for Biofilm Engineering (CBE). The CD has published over 600 research articles in professional journals, and is known throughout the world in the microbiology scientific communities.

Question One

How do you identify new Center partners from industry and establish contact with them?

The Center Director (CD) reported that the best method to establish contact with industry is by publishing extensively. He reported that industrial personnel have noticed faculty research, emailed the Center faculty, and usually established a testing contract to test the facilities and Center personnel before joining the ERC. The CD reported that a relationship has to be built before the companies will join a Center, and that is established through having high quality testing equipment within the research facilities, which allows the testing to be conducted for the company.

The Center Director for the Center for Wireless Integrated MicroSystems (WIMS) reported that the Center has had interactions for many years with numerous companies that focus on the basic microelectronic and instrumentation data gathering

fields. The CD reported that when the Center for WIMS was formed, Center personnel contacted twenty-five companies that were suggested by the Center faculty. The Center faculty had previous interactions with various companies and they were familiar with many of the companies that had hired their graduates. The identification was made on the basis of prior contacts, and they included many microelectronic companies, which included Motorola, Intel, and Texas Instruments.

The companies were from a variety of industrial sectors interested in Center research, such as the medical and oil companies and the automotive companies interested in sensors. Some of the companies were interested in making the instrumentation and others were interested in using the instrumentation. The Center has a variety of companies both large and small, and they were identified by faculty awareness, and through faculty from a number of Michigan universities. Center personnel contacted the prospective companies, and explained to the industrial personnel what the Center was doing. The CD reported that it was important to have a contact in the company from upper management because the annual membership fee is $50,000 for the Center for WIMS. For some companies, the contacts were needed at the Vice President level in order to approve the $50,000 annual membership fee.

The CD reported that multiple champions in each company are essential for maintaining Center memberships. He reported that the first step has been to enlist the companies as members of the Center, which creates more opportunities for individual contracts with specific faculty.

Question Two

Does the industrial Liaison Officer (ILO) ask the Center Director (CD) for industrial leads?

The Center Director (CD) for the CBE reported that he acquired most of the leads for the Center because of his extensive lecture schedule and attendance at numerous national and international conferences. The CD reported that he identifies approximately 8-10 industrial leads per year, and he invites them to the Technical Advisory Conferences (TAC) at the ERC. He reported that he passes the prospective industrial contacts to the Center Industrial Liaison Officer (ILO). The Center ILO answers all the industrial emails, performs all the duties of recruiting and enlisting the industrial members, and coordinates the Technical Advisory Conferences (TAC).

The Center Director for the Center for WIMS reported that he acquires about 50% of the industrial leads for the Center, while the Center faculty provides 50%. The CD reported that the Center ILO asks the Center faculty and the CD for industrial leads. He reported that there exists an informal system where the Center faculty informs the ILO of the industrial contacts through email. The ILO follows-up the leads by sending the prospective companies information on the Center Industrial Program, and the ERC Annual Report, which lists all of the Center's current research projects.

The industrial leads that the Center has accumulated and the status of their interactions are reviewed at the weekly Center meetings. The CD reported that the Center staff weekly examines the status of the prospective companies, their position in the membership process, and the actions the faculty or Center personnel have performed, and

will perform to help the prospective companies advance to the membership program.

Question Three

How many patents are a result of your Center research?

The Center Director for the CBE reported that approximately fifteen patents are the results of Center research, and the royalties are about $15,000-20,000 per year for the Center. The CD from the Center for WIMS reported there are approximately 20-25 patents that have been filed, but many of those have not been issued because the Center is only in the fourth year of existence. Of those that have been filed, some are from grants and contracts, and the others are from core support, which comes from the membership fees. The industrial members have first priority on those patents. Additional patents have come out of projects funded by federal agencies, such as DARPA (Defense Advanced Research Projects Agency) or NIH (National Institute of Health).

Question Four

Has your Center spun-off companies which have become industrial members of your Center ?

The CD from the CBE reported that a small company was spun-off from the Center, but the company did not become an industrial member. The small company has used Center connections for marketing its product. One company has commercialized Center technologies that had been a member for a year, but currently, is a member of the Montana consortia, and receives the same benefits as a full industrial member. Both small companies help in marketing Center research, and excellent relationships have been

maintained with the companies.

The CD from the Center for WIMS reported there have been 3-4 companies spun-off from the Center, and another 3-4 companies spun-off from the research Center before the ERC was affiliated with the NSF. The Center has always been a large research center, and existed for two decades prior to the NSF funding it as an ERC. All of the companies that have spun-out of the Center are industrial members of the Center.

Question Five

How many technologies has the Center transferred to industry?

The CD from the CBE reported that many technologies were developed at the University of Calgary, refined at the CBE, and approximately ten technologies have been transferred to industry, such as, equipment designs, biofilm reactors, extraction solutions, and testing technologies. The CD reported that a few technologies have transferred to small companies but many of the technologies that have been transferred have been given freely to industry and federal agencies.

The CD for the Center for WIMS reported that the Center has transferred devices and sensors to industry, but the NSF Center is only in the fourth year of existence and is in the process of producing prototypes. The CD reported that the Center had approximately six technologies that have transferred to industry before being funded by the NSF as an ERC. There have been a number of processes and devices that have been commercialized such as, gyroscopes, pressure sensors, and infrared detectors. The CD claimed that it may take more than three years to move devices into commercial production and there are a number of commercialized cases before the Center became

affiliated with the NSF. The Center should have commercialized products within the next few years.

Question Six

Does the Center usually grant exclusive licenses based on the amount of expenditures for research that a company has provided at your Center?

At the CBE, the CD reported that the Center grants exclusive licenses to companies based on the amount of money they spend on research. When a company has an idea, they usually bring it to the Center for testing, and the Center charges the company $50,000-60,000. The Center will keep the results confidential for a length of time, and the company receives the Intellectual Property (IP) because the Center just performed the testing for a fee. If the company spends above $80,000, the company owns the full IP, which has been arranged by the university technology transfer office. The companies may receive the IP, even if the Center has an idea to go with it. The CD reported that it rarely occurs where the university makes a discovery, industry licenses it, the university performs some testing, and the two parties share the royalties. The CD reported that many potentially patentable ideas disappear, and it would be more beneficial to receive a negotiated amount of money, and give the potential IP to the company. The CD stated, “I have seen the patenting skills of university patent offices, and the legal skills of 8-10 patent attorneys at 3M. From my past experiences in trying to patent an invention from the Center, it is better to accept the money from industry, and let the companies worry about the patents.”

The CD from the Center for WIMS reported that the Center does not grant exclusive licenses because the Center only has two membership grades. One grade is for small companies in Michigan, and the other level has a $50,000 annual membership fee. The State of Michigan has provided money for the Center to encourage start-ups for small Michigan companies. The Center does not have a higher level of license that would carry with it an exclusive license. The CD reported that only the university technology transfer office can grant exclusive licenses to industry, and they usually do not grant exclusive licenses. The technology transfer staff may grant exclusive licenses for a field of use only, but it would be negotiated on a case-by-case basis.

Question Seven

How do you articulate your vision of the ERC to industry?

The CD from the CBE reported that he uses three guiding principles, which are cutting edge research, student education, and technology transfer to industry. He claims that the Center has been successful at technology transfer to industry, but not at bringing royalty money back to the Center because most of the technology is freely given away.

The CD for the WIMS Center reported that he articulates his vision of the ERC to university personnel, Center staff, industry, the NSF, and Center visitors. The CD claims it is important that the industrial personnel perceive the vision of the Center, and the most formal method for accomplishing the vision is through the semi-annual meetings at the Center, and at the annual reviews with the NSF. The CD informs the prospective industrial members of the applications of Center research, the importance for addressing healthcare, implantable devices, home healthcare, home monitoring, Internet monitoring,

and homeland security. For homeland security, the Center has been developing monitors for chemical warfare agents that can be used in the field. He reported that the sensors developed at the Center have performed better than any other monitors on the market, and the Center for WIMS and many of the NSF ERCs are addressing numerous research areas that will greatly impact society.

Question Eight

How do you articulate your vision of the ERC to university administrators?

The CD for the Center for Biofilm Engineering (CBE) reported that Montana State University is the smallest and least prestigious university to receive a NSF ERC. The university has decided to harness the ERC, and provided tremendous support for the Center. There are twenty-two ERCs in the U.S. and they are funded for 11 years at a minimum of $2 million per year. The CD claims he has informed NSF administrators that the Center is permanently successful in regards to university support. The Center has been an important resource for students, and the main reason companies visit the campus. After the NSF funding ended, the university gave the Center a better rate on indirect research costs (IDCs) and currently, the Center research funding is higher than when the Center was funded by the NSF, which is a tribute to the university's support.

The CD from the Center for WIMS reported that the University of Michigan administrators have been very supportive of the ERC, because they understand the business of the Center, the university gains IP from Center research, and the university receives royalties from the leased inventions. The Center for WIMS has been very visible because it is interdisciplinary and involves numerous departments.

The CD reported that when Center personnel have presented their research to the university personnel, the university administrators were always impressed. Technology transfer has evolved over the years at the University of Michigan, and start-ups and entrepreneurial activities have been regarded as significant indicators for how the Center performs. The Center has been disseminating the knowledge produced by the university, insuring that it is applied to the public good, and adhering with the mission of the university. The CD reported that the Center has accomplished more than publishing in the technical journals; it has impacted employment, and enriched the area in which the university resides.

Question Nine

Have you established research alliances with other universities?

The CBE has established research projects with the University of Washington Engineering Biomaterials Center, which is a NSF ERC that specializes in biotechnology. The University of Michigan Center for WIMS has established alliances with 6-7 other universities. When the Center was initiated, Michigan State and Michigan Technological University were available to partner with the University of Michigan. The collaborative partnerships were historically related because the State of Michigan encouraged research in MicroSystems and envisioned having State-wide research activity. Michigan State University brought expertise and materials, and Michigan Technological University brought important expertise in packaging, molding, and mechanical engineering activity that the Center for WIMS did not possess. The Center continues to have collaborative research ties with the Michigan universities. Additionally, the Center has alliances with

minority-serving institutions, and the connection has improved the diversity of the Center. There are 4-5 additional universities that are in the process of setting up joint research collaborations with the Center for WIMS.

Question Ten

Have you established research alliances with other federal agencies?

The CD from CBE reported that the Department of Defense (DOD) awarded the Center a $1 million research allocation in 2004 for biofilms and bioterrorism. The agency has provided assurances for additional funding to the Center. Additionally, the National Institute of Health (NIH) has provided biofilm dental grants, and the Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA) have provided grants for methods development.

The Center for WIMS has received funding from many federal agencies and a portion of the funding is long term. The total amount of funding for the Center in 2003 was $14 million. More funding was provided for MicroSystem activities, with major support from DARPA and NIH, some support from National Institute of Occupational Safety & Health (NIOSH), and homeland security support from the federal research facility, Sandia Laboratories, in New Mexico.

Question Eleven

What are your best marketing methods for building ERC-industry partnerships?

The CD from the CBE reported that the industrial memberships are an outgrowth of the Center presentations and the publications of the Center faculty. The best marketing

methods are to have excellent publications and presentations at conferences all over the world. The CD reported that many contacts occur after a presentation or after a publication is released. The second best marketing methods are the ERC web site, and the Center faculty web sites. Industry has personnel paid to listen, attend conferences, read papers, and find the Center faculty if they have a problem. The Center receives approximately $500,000 for industrial memberships, and $1.1-1.2 million for sponsored research per year. Center personnel have performed numerous tests for companies because the Center has the methods, facilities, and the trained personnel.

Industrial tests are a large profit source, and have been more profitable for the Center than industrial memberships and sponsored research. Center personnel have to draw out company problems in privacy, since a company's competitors are always watching and listening. Center personnel, first perform their presentations in a collective environment, and then opportunities are created for an individual company to inform the Center faculty of a company problem, under a confidential disclosure agreement.

The CD at the Center for WIMS reported that the best methods for building Center-industry partnerships are through direct personal contacts with industrial personnel, a shared vision among personnel, and Center-industry partnerships have to begin early to succeed. There has to be a shared commitment with the Center and industrial personnel. When projects arrive at the research prototype stage, the company can take over and move the project into the engineering and manufacturing prototype stage, and eventually, advance to commercializing a product. It takes Center personnel and industrial personnel working together for a project to succeed. Additionally, the CD

reported that the Center ILO was the Chairman for the Commercialization of MicroSystems Conference last year, which greatly enhanced the marketing of the Center to industry.

Question Twelve

What methods have not improved Center-industry partnerships?

The CD at the CBE reported that guessing what companies may be interested in Center research and making cold direct calls to the companies does not work in attaining Center-industry partnerships. The CD at the Center for WIMS reported that the current economy has caused the tightening of industrial personnel traveling schedules. Many of the industrial sectors are financially conservative at this time. Cold selling to prospective industrial members usually fails and the Center literature received by unknown industrial personnel usually is discarded. Many busy industrial personnel do not want to be bothered, but Center personnel make an effort and contact the companies to keep the industrial members abreast of Center research.

Question Thirteen

How has the Center marketing strategies with industry evolved over the years?

The CD at the CBE reported that when the Center was first established in 1990, the industrial members of the Center were mainly engineering and oil companies. Currently, the oil and engineering companies are less than a third of the industrial membership and two thirds of the industrial members are general biofilm, medical, and dental companies. Center faculty were not performing medical research when the Center

was funded by the NSF because the NSF and NIH try not to encroach upon research subjects. But in 1999, the NSF actively encouraged Center faculty to look at medical problems. Currently, medical related companies are more than half of the Center's industrial membership, and more than 80% of the sponsored research. There are many medical problems related to infections in medical devices, and the Center performs many tests for industry in this area. The CD reported that industrial support has been the Center's lifeline for supporting Center infrastructure, and the sponsored research has provided profit margins for the Center. With sponsored research, the industrial members receive Center data, the Center receives financial support for technicians, research engineers, and for the infrastructure, which make Center research activities different from the academic fields.

The CD reported that in the earlier years, the Center was mainly supported by the NSF, but industrial support has been steadily increasing and went up sharply in 2002. The Center has received an $8 million grant from the Murdock Foundation, and a $1 million grant for bio-terrorism.

The CD for the Center for WIMS reported that attendance at the semi-annual Industrial Advisory Board meetings for the industrial members has increased because the Center changed the format of the meetings. The Center use to conduct the meetings like mini-conferences with a poster session and highlight talks, but industrial members were not satisfied with the format. Currently, the meetings consist of overviews by thrust leaders, and the poster sessions. The CD claims the meetings are more effective allowing participants to network with Center and industrial personnel, and attend only the

overviews or posters that are of the most interest for their companies. The CD reported that having personnel networking and walking throughout the conference facilities has improved the IAB meetings. Additionally, the Center graduate students make a one-minute presentation of their research projects, and they are available for the poster sessions. The new method allows industrial personnel to choose which student and poster session to visit.

Industrial Liaison Officers Interview

The Industrial Liaison Officer (ILO) at an ERC is responsible for tracking all prospective industrial leads, contacting industrial members for membership, and organizing and managing the semi-annual Technical Advisory Conferences. In addition, the ILO duties include the annual NSF site reviews, workshops, directing corporate personnel to the appropriate thrust leader, enlisting the assistance of the technology transfer office for patenting of inventions, and marketing of the Center to prospective industrial members, university departments, federal agencies, and other universities.

The ILO at the Center for Biofilm Engineering at Montana State University has been employed at the ERC for six years. The ILO at the University of Michigan Center for WIMS has been employed by the Center for four years, and was formerly with industry for thirty years. Twelve survey questions were answered by the ILO at each ERC, and are reported in the following section.

Question One

What kind of system do you use for tracking Center-industry interactions ?

The Industrial Liaison Officer (ILO) at the Center for WIMS reported that he does not use a software program for tracking Center-industry interactions, but he maintains a recorded log of interactions with industrial personnel. The ILO at the CBE maintains records of Center-industry interactions, which include email and telephone conversation records, and Center faculty maintain individual records of interactions with prospective industrial members. When faculty meet a prospective industrial member, the faculty inform the ILO of the lead, and the ILO contacts the prospective member. A software system is used to track the number of times a Center faculty web site is visited by outside personnel investigating the web site.

The ILO reported that the most effective way of interacting with prospective members has been through formal invitations to industrial personnel to visit the ERC, industrial attendance at TAC meetings, and faculty visiting industrial sites. The Center visit not associated with a TAC meeting has been effective, since it has provided the prospective member with the most attention from the Center faculty. A Center visit involves a full day of meetings with at least six of the Center faculty, short presentations, and question and answer sessions that assist faculty to better understand the challenges that confront the particular company.

Question Two

How do you determine which companies to approach for industrial membership?

The ILO at the CBE reported that companies often contact the Center seeking information on biofilms or they may have a biofilm industrial problem, and converse with a particular faculty member, the ILO, or the Center Director. The Center has

received leads from existing industrial members who inform Center personnel of companies that are interested in Center research and the personnel to contact. Other methods have involved industrial representatives attending conferences and presentations on biofilms, and eventually contact one of the Center faculty. The ERC sends Center literature and research information to key industrial personnel, but only after analyzing and insuring that the companies would benefit from Center research. The Center has provided a subscriber list through the Center web site that enables industrial personnel to subscribe to a monthly Center newsletter.

The ILO at the Center for WIMS reported that he examines the interests of companies and initiates relationships with key industrial personnel. The ILO works closely with Corporate Relations personnel in the College of Engineering at the University of Michigan. When a company that employs UM alumni expresses an interest in Center technology, the ILO will initiate a relationship with the alumni. The ILO reported that he attends many technical conferences within the area, and meets many industrial personnel at the conferences.

The ILO reported that he prefers to work with the larger companies unless they are small Michigan companies. The ILO claims that the small companies are difficult and require more effort if they are a great distance from the Center, and they require more capital. The $50,000 industrial membership fee usually nullifies most partnerships with the small non-Michigan companies. When the small company is from Michigan, the annual Center membership fee is $10,000 because the State of Michigan provides money to the Center to foster the Michigan small companies.

The ILO reported that there are two sides to working with small companies. If a small company pushes some technology, and a large company recognizes it, then the large company can buy the small company without taking the risk and investment that the small company has gone through. In contrast, the large company may complain for having to pay the $50,000 membership fee versus the $10,000 small company membership fee, and claim that the company is funding the competition.

The ILO reported that companies are interested in the intellectual property (IP), faculty, and students at the Center, but the small companies do not receive the IP. The large companies, who pay the higher fee, are able to acquire the better deals and they receive the right of first refusal of Center technologies. In the Center consortium, all the industrial members have pooled their membership money, receive research results, and may license the IP. Some companies that are close to finding a solution for a particular research project, may support sponsored research with the Center. With sponsored research the company can obtain a better deal with the University of Michigan (UM) Technology Transfer Office. If the company sponsors research and they pay a certain amount, the university may grant an exclusive license or give the company most of the IP, but it is always negotiable with the university personnel.

Question Three

Who provides you with the greatest amount of leads?

The ILO at the CBE reported that the Center web site provides the Center with the greatest amount of leads, but the Center Director (CD) provides the Center with the best leads. The CD travels an incredible amount and meets many industrial personnel that

are potential industrial members. Some of the companies have joined as industrial members, but many only sponsor Center research and do not join the Center, which has greatly contributed to the Center budget.

When the CD and faculty attend conferences to make presentations, and they have encountered industrial representatives that are interested in Center research, the Center personnel pass the leads to the ILO upon their return to the ERC. The ILO reported that he makes an assessment of the prospective industrial members to determine if the companies are sponsoring research, joining the Center, or having Center personnel perform testing for the company, and he contacts the appropriate personnel in the company.

The ILO at the UM reported that Center faculty thrust leaders and the College of Engineering Corporate Relations personnel provided the greatest amount of leads. The ILO at Center suggested that large companies are better able to understand and predict the direction of the technology because they are heavy users of numerous technologies. He reported that the technologies developed at the Center are applied to a large number of potential companies, which includes the manufacturers and the users. The ILO reported that the financial decisions are made at the Vice President (VP) level, and companies are searching for research solutions that can be completed with less funding. Additionally, he claims that companies want directed research, to solve next year's problem, and they look for specific universities to solve it cheaper than within their companies.

Question Four

Do you ask the Center Director, Center faculty, inventor, and university technology transfer personnel for leads?

The ILO at the CBE reported that Center personnel understand how the Center is funded, and if the CD or faculty discover industrial personnel who are interested in Center research, they pass the lead to the ILO. The ILO reported that the Center faculty prefer to pass the leads to the ILO, and concentrate on faculty research projects.

The ILO at the Center for WIMS reported that the reporting of leads is very informal. Center faculty pass industrial business cards and contacts of prospective industrial personnel to the ILO of the Center. The ILO reported that there is a tremendous amount of lead reporting, and it takes a large amount of effort to enlist companies. The ILO suggested that the industrial strategy has changed in many companies, and currently, companies are more mission-driven to get research solved in the next year. The ILO reported that a company representative stated to him that, “I know I should do this for the next three years, but let me tell you what I have to do for next year.” The ILO claimed that the industrial mission is opposed to what the NSF seeks in an ERC. The ILO reported that the NSF has to educate the companies to the many advantages of joining an ERC.

Question Five

How many patents have been granted by your Center?

The ILO at the Center for WIMS reported that the Center is in the fourth year of funding with the NSF, and there have been no patents issued. The Center has

approximately 17 provisional patents, but eventually, the patents have to be converted to utility patents or be abandoned.

The advantages of the provisional patent are that the Center receives the patent within ten days with very few requirements, it provides one-year protection, and it has been a quick method for protecting data. A provisional patent costs approximately $6,000 per patent, and Center personnel must decide within the year which inventions will warrant seeking a utility patent. The Center charges the companies $3,000 for an option to look at an invention, and if the company obtains the patent, the company has to pay all the associative costs of the patenting process. All negotiations for licensing are through the university technology transfer office, and no companies have left the Center over the negotiation of IP rights.

Question Six

How many technologies have been transferred to industry?

The ILO at the CBE reported that a few technologies have transferred to industry, and that industry mainly values the information that they receive from Center research, and not necessarily the technologies. The Center has developed many biofilm methods, which are important to the companies and maintains their memberships. The ILO at the CBE reported that many of the Center innovations do not involve the transfer of IP, but the transfer of knowledge, which is absorbed by the industrial members. The ILO at the Center for WIMS reported that there has been one transfer of a technology, and one technology has received a patent.

Question Seven

Does the Center usually grant exclusive licenses to corporate sponsors who provide large amounts of research support to the Center?

The ILO at the CBE reported that when a non-member approaches the Center for proprietary research for a specified amount of money, the Center and the company enter into a confidentiality agreement. If the company wants to own the IP that results from the research, a negotiated contract with the university is required. The negotiation usually results in a joint ownership of the IP, but if the company wants complete ownership, the company must become a premium member of the Center. The premier membership dues are significantly higher and cost $80,000 per year, but the company receives 100% of the IP rights. The Center has no premium members because many of the companies that support Center research and need partial ownership of the IP, negotiate an IP agreement with the university. Usually, the parties come to an agreement, and often the agreement might be that the company owns the exclusive rights to the use of the invention for their industrial application, and the university retains the right to sell the invention to any non-competing application. The company may own the patent, but it must be negotiated with the university technology transfer office, and some negotiations with companies were unsuccessful. The ILO at the Center for WIMS reported that the university seldom grants exclusive licenses. He claimed that no company has withdrawn from the Center because an exclusive was withheld from the company.

Question Eight

What is the most successful method that brings in corporate sponsors?

The ILO at the Center for WIMS reported that personal contacts with the industrial personnel as opposed to formal presentations have been the most successful in attaining industrial members for the Center. The ILO suggested that one-on-one interactions with industrial personnel and discussing specific company needs have been successful. Industrial personnel want Center research that can be useful for the company, they want to be informed of the advantages and disadvantages of the research, and they want to know how Center research can solve their company problem.

Center faculty and students with specialized expertise were matched with companies to remedy industrial problems. When working with very large companies, various research divisions within a company have been interested in different research areas. With the very large companies, it has been advantageous for the Center to inform multiple divisions within the company of the Center research. The ILO claimed that some of the large companies are so disjointed that many personnel are unaware of other divisions in the company.

The ILO indicated that Center personnel have developed multiple contacts in the companies because the industrial Center champions can be transferred or retire. Additionally, because the large companies have industrial sites in multiple countries, it has been difficult to inform all industrial personnel of Center research activities and results.

The ILO at the CBE reported that the most successful method for bringing in industrial members has been the Center Director visiting company sites, and making presentations to the industrial personnel. Usually, after the CD presentation, industrial

representatives visit the Center, meet with faculty, tour the facilities, and eventually, become members of the Center. Additionally, Center personnel analyze the competitors of their current industrial members, and solicit the competitors to join the Center.

Question Nine

What is the Center's strategic marketing plan for recruiting industrial members?

The ILO at the Center for WIMS reported that the Center strategy has been to increase their personal interactions with companies through the Center and the university. The university has many alumni that are employed with large companies that want to be associated with the University of Michigan because of the institution's research reputation. The ILO reported that the Center strategy has been to interact with alumni and industrial personnel that visit the campus that have an interest in Center research. One marketing strategy has been to selectively attend large Micro-Electronic MicroSystems (MEMS) and transducer conferences. Center personnel attend conferences, and present their research to industrial personnel who are interested in MEMS. The Center concentrates on finding, convincing, and interacting with multi-level industrial personnel, which includes managers and Vice Presidents who make the company financial decisions. The ILO reported that companies are prudently managing discretionary spending.

The ILO at the CBE reported that the Center's marketing strategy has been to target companies that can benefit from Center research, and to contact the best industrial person within the company. Another marketing plan has been to target conferences and meetings that federal and industrial representatives attend which pertain to regulation

development and match with Center research. The Center has been involved with regulatory agencies, and advising them about specific methods of research. The Center research has brought Center personnel into contact with many companies who are developing products and seeking registration or approval from regulatory agencies for their products, such as, the FDA or the EPA.

The ILO suggested that industry needs to have an informed regulatory community in order for the companies to effectively develop products. The regulatory agencies have not been at the forefront of method development because of being under-funded. The agencies work in an environment that is hostile to regulation in general, and the agencies depend on the Center research to inform agency personnel of the various research methods in specific fields. Center personnel inform the regulators of the research methods, which assists the Center industrial members in being able to know that the regulators will react in a predictable manner. The ILO reported that industrial personnel want to be informed of the required agency policies.

Question Ten

What is the least effective method to enlist industrial members to your Center?

The ILO at the CBE reported that cold calls are the least effective method to bring in industrial members to the Center. Another method that failed was having a student identify potential companies through web sites. Out of four hundred researched web sites, the Center obtained five prospective companies that did not join the Center.

The ILO at the Center for WIMS suggested that the cold calls and mass advertising are the least effective methods to bring in industrial members to the Center.

The ILO stated, that “unless industrial personnel are interested in Center faculty research, Center personnel are wasting their time.”

Question Eleven

What are the best methods that help maintain the current industrial members?

The ILO at the Center for WIMS reported that personal contacts between Center faculty and industrial personnel, and at multiple corporate levels when dealing with large corporations, have contributed to maintaining current memberships. The personal contacts consist of Center personnel visiting industry, or industrial personnel visiting the Center and meeting with the Center faculty. Industrial personnel visit the Center through an Industrial Speakers Series Program, and meet the Center faculty and students.

The Center for WIMS has a Resident Engineer Program, which allows the company to send an employee to the Center for $60,000 per year. The industrial personnel receive access to the university labs, faculty, and students. Many companies use the program to reduce the cost of maintaining expensive industrial labs. The Center lab uses commercial grade equipment, which is important when transferring technology. In order to maintain consistent research results, commercial equipment is mandatory over homemade equipment.

The ILO reported that the Center personnel provide constant interactions with the industrial members by having a faculty member assigned to each company. The faculty member contacts industrial personnel to discuss company research problems and solutions, and informs the company that the Center is available to do sponsored research.

The ILO at the CBE reported that the best methods for maintaining Center

members have been to help the industrial representatives show value in their Center membership to industrial upper management. The value may come from results from specific research or it may be through solving a company problem through interactions between Center and industrial personnel. The ILO reported that for the majority of the members, the industrial champion has to justify the annual membership to upper management.

Question Twelve

What methods have caused industrial members to not renew their memberships?

The ILO from the Center for WIMS reported that changes in management caused one company to leave the Center. The industrial researchers and managers were interested in maintaining their Center membership, but due to financial reasons and the transfer of the champion, upper management denied the renewal of the Center. In another case, two large companies left the Center because industrial personnel were not using the Center research, and the companies had financial constraints. The companies reported they would acquire the technology from another source, announced large personnel layoffs, and reduced industrial research. The ILO reported that most of the companies that have not renewed their memberships have been a result of companies deciding not to manufacture Center technology, and placing more reliance upon their suppliers.

The ILO from the Center for WIMS reported that the companies that are leaving the Center do not understand the advantages of joining an ERC. The ILO reported that the NSF and the ERCs need to inform industry that the ERCs provide a unique education for students. The ILO claimed that the ERCs train students to address a system as

opposed to a narrower view. The ILO stated, that “most Ph.D. students are trained to be the world’s greatest expert on making inventions, but when they are trained at an ERC they insure that their invention fits into a system. Academia has started to recognize this concept, while industry has long recognized the concept, and they want engineers that understand it.”

The ILO reported that industry has not recognized that when Center personnel design a system, they understand how all the components in the system fit together. For example, in packaging and calibration, the testing personnel usually do a good job in designing an element and making an electronic, but then they have to package it. The package itself is extremely difficult because if the engineers package it one-way, they find out it impacts the performance of the system. In many cases, researchers must return to the fundamental design, and when they realize that the design has a problem they have two options. They can “bite the bullet” and continue because they do not have time to redesign the whole system, which adds cost and complexity to the system. The other option is to go back and admit they made a mistake, and redesign it, but both options are time consuming and expensive. The Center personnel must acquire more than one champion in the company, and they have to be constantly contacting and interacting with industrial personnel.

The ILO at the Center for WIMS reported that the NSF mounted a campaign to inform companies of the advantages of membership in an ERC as opposed to hiring a professor as a consultant. He claimed that the advantage of joining the Center is that the company has the opportunity to sample many research personnel. Many companies are

project oriented in the way they use universities, and they are being driven to conserve money. Usually, a company wants a particular Center faculty to perform a project and the company wants the answer the following year. The ILO reported that companies lose the benefits of a large group of researchers working on a generic problem. In many of the companies, they call it R&D, but it is really 98% Development and 2% Research. Center personnel can attempt to change the industrial attitude by informing upper management, that Center research provides an opportunity for the company to build a solid research foundation and develop a technology, as opposed to just solving their immediate need.

The ILO reported that companies can receive more for their research dollar by the ERC performing generic research, and eventually applying that research in very specific areas by either bringing that technology or knowledge inside the company or funding sponsored research in the Center. The ILO reported that companies are making decisions that are short term because they are being pushed by economics. The ILO claimed that the ERCs can help companies manage industrial risk because they can subsidize research in a consortium type of arrangement.

The ILO reported that upper management should set aside research money for long-range development, which can be accomplished by joining an ERC and working on very specific projects. The ILO reported that many companies do not look that far into the future. The ILO stated that “companies want an answer tomorrow, and they ask Center personnel where to spend their research money to obtain tomorrow’s solution.”

The ILO reported that the ERC can help the companies lay out their technical strategies, solve some immediate problems, evaluate applications in the technology, and

evaluate the best technology to address the company problem. The ILO reported that maintaining industrial members requires that Center personnel demonstrate the value of Center membership to the companies.

The ILO at the CBE reported that the number one cause for companies leaving the Center has been the champions leaving the companies. The ILO reported that currently, one industrial member, and three champions of the Center have left the company. The champion and his team had been one of the Center's strongest supporters, but there was a change in management. The Center has been trying to reestablish the relationship with another employee in the company. The Center has identified the company employee, and plans to invite him to the Center. The Center marketing effort has been similar to a new member except the prospective industrial personnel have knowledge of the previous industrial personnel's belief in the Center.

The ILO reported that industrial members have left the Center when the companies were involved in mergers or acquisitions, and the industrial champions were reassigned. The ILO reported that the Center had companies leave because the results of the sponsored research were different from what they expected, and they did not renew their membership. The Center has long-term members that have been with the Center for 10-15 years, and some members that have joined three times. For members that have rejoined the Center, their companies faced financial constraints, and they rejoined when they realized that the Center was beneficial for their company.

Center personnel are informed that membership in the Center for many companies has been an economic decision. If a company has been doing well financially, their

management has justified membership in the Center. The ILO reported some long-term members are having trouble receiving travel funds for the semi-annual Center meetings because their stock price has been low, and their CEO has denied non-essential travel for the company. Maintaining industrial memberships have become more challenging with a poor economy, and asking companies for a $20,000 membership fee each year has been a sensitive economic issue.

The ILO reported that small Montana businesses may join the Center without paying a membership fee, and receive the same benefits as the larger companies, except that they have no vote on policies within the Center. Many of the small companies do not have enough resources to benefit from a Center membership because their R&D has been too specialized, and has not been related to Center research. There are approximately 4-5 small companies in Bozeman, Montana that have joined the Center.

The ILO has asked the industrial members about consortia memberships, particularly among the smaller testing companies. The testing companies have taken one of the methods the Center has developed, and used it commercially for testing for biofilms. The ILO reported that he asked several small testing companies if they would pay a reduced $5,000 Center membership fee to join the Center. The ILO reported that the company representatives claimed it was too much. The ILO reported that the Center can not receive less than $5,000 for memberships in order to maintain the Center support base.

University Technology Transfer Personnel Interviews

University technology transfer licensing officers are responsible for taking invention disclosures from faculty, filing for patents, marketing of university and ERC inventions to the corporate sector, and negotiating exclusive or non-exclusive licenses with companies seeking university inventions. Two interviews were conducted with university technology licensing officers (LOs) from the University of Michigan and from Montana State University, Bozeman.

The University of Michigan has a large technology transfer office for licensing, and they additionally, have an office within the College of Engineering that is responsible for ERC inventions. One of the interviews was with a licensing officer(LO) at the UM College of Engineering, and the other interview was with a licensing officer within the Technology Transfer Office at Montana State University, Bozeman. The technology transfer office at MSU has three personnel for marketing university and ERC inventions to the corporate sector.

Question One

How many personnel in your technology transfer office are responsible for the ERC technology transfer processes?

The technology transfer officer from the UM College of Engineering reports that he devotes one half of his time to the Center for WIMS, and the university technology transfer office at the University of Michigan has one person that commits one half of her time to the ERC. This is equivalent to one full time employee for the handling of Center

technology transfer activities.

The technology transfer officer at Montana State University reported that the technology transfer for the university employs three personnel. No one is assigned the ERC, but all three personnel are responsive for the technology transfer activities of the ERC when a situation arises for their services.

Question Two

Do you ask the ERC faculty, the Industrial Liaison Officer, Center Director, or inventors for industrial leads?

The technology transfer officer at the University of Michigan (UM) College of Engineering reported that technology transfer personnel ask many Center personnel for leads. One method that the LO has used to obtain leads has been through the disclosure process. This occurs when the inventor discloses their invention to the UM technology licensing personnel. Usually, the inventor names the interested company, and the contacts within the company on the disclosure form. The other method has been to ask the Center ILO and faculty for the targeted companies and contacts. The LO reported that he has used marketing research to find companies for Center inventions. He reported that when he performs a patent search, he discovers which companies are filing for patents, and additional contacts are found within the literature. He claimed that he has found a few companies by using these methods, but it has been a time-consuming process. The LO reported that it has been more effective to ask the Center faculty member which industrial personnel are the better prospects.

The LO at MSU reported that the leads are revealed during the disclosure process.

The LO reported that when necessary he has asked the inventor, ILO, or Center Director for additional leads, but the inventor has provided the best leads for licensing of inventions.

Question Three

What university policies make it easier for industrial members to join the ERC at your university?

The LO at MSU reported that the university provides a 50% share for inventions, and the generous policy has motivated faculty to invent and work with industry He reported that the university IP policies are negotiable with sponsored research agreements. The university has provided an industry favoring policy with no indirect costs (IDC) taken out of the industrial funds. A university policy has insured that the industrial research funds will be used directly for research projects, and that the university policies have been responsive and favorable for the Center.

The university has a premier-level industrial membership, which provides the opportunity to own 100% of the IP, but currently, there are no premier level industrial members at the Center. The LO reported that when industrial members sponsor research, the companies' receive options on the licensing of the IP. The delay of publications has ranged from three months to a year, and the length of time has depended on the IP and patent negotiations.

The LO at the UM reported that the more industry benefits from the ERC, the easier it has been to enlist industrial members. The Center for WIMS has provided more favorable membership fees to smaller companies. The LO reported that the IP terms are

explained to the companies before they join the Center. The UM has not been flexible in the negotiation of the IP, but the companies have the opportunity to negotiate with the UM technology transfer office. The LO reported that it probably would be more advantageous if the university were to have options in their policies that offered more favorable IP terms for industry when they provided more financial support for research. He reported that the university has very good terms because there has been a large amount of industrial support for the UM. The LO reported that the low membership fees for the smaller companies has enabled more companies to join the Center, and the smaller companies receive the same benefits as the larger companies.

Question Four

What are the best methods for the marketing of Center inventions to industry?

The UM LO reported that one of the best methods has been the semi-annual Industry Advisory Board (IAB) conferences where faculty and students present Center research to industrial personnel. The LO reported that the conferences have provided an opportunity for marketing Center inventions to companies because licensing staff are able to inform many industrial members at the same time. Other methods that have been successful are Center faculty making presentations at conferences, and focused patent searches. The patent search method has been successful because it has allowed the LO to find related patents, and the personnel who are filing those patents.

The LO reported that a successful marketing method has been marketing multiple inventions in a package versus marketing one invention individually. He reported that he finds the Center's strongest research in a couple of technology areas, and markets the

package to industrial personnel who are interested in the technology areas. The LO reported that an additional marketing method has been through the Center faculty making presentations at technical conferences. After the conferences, the Center faculty and the licensing office usually, receive many calls from interested industrial personnel.

The LO reported that methods that were unsuccessful were using local consulting companies, who contacted companies for a particular technology, and making cold calls to prospective industrial companies. The LO indicated that finding the key decision-maker within the targeted company for the technology has been difficult. The process has involved a matching of Center technology to a product and company, and finding the right personnel to contact. He reported that to be successful, the LO has to make an excellent, concise, and quick presentation. Another method that is used is putting a technology opportunity listing on a university Web site or ERC web site.

A method that was not successful was a Center faculty member presenting a technology through a video-conference, and having industrial personnel watch the presentation. The LO reported that he did not allow enough time to draw more participants or continue with the method.

The LO at Montana State University (MSU) reported that the best method has been to acquire leads from the inventor and from companies that have previously sponsored research at the Center. The LO reported that he contacts the companies by telephone or email, provides them with a technology description, and follows-up with the companies to see if they are interested in the technology. He reported that he uses the ERC's industrial membership files, and he contacts the industrial members when the

technology is a match for the company. The LO use to be the ILO at the CBE, and is very familiar with the Center research, faculty, and the industrial members.

The LO at the UM reported that a method that has been successful has been marketing and sponsoring technical forums with Center personnel, which has provided opportunities to inform the industrial members of Center technologies. He reported that the Center has had a few inventions licensed, and the leases are providing revenue for the university. He reported that the UM has to improve their Web site because it has become a reference for many prospective companies. The LO office has performed marketing searches to find the right personnel and companies to contact for licensing and marketing the Center technologies. He reported that performing marketing research, contacting the right industrial personnel, and making direct contact have been very important in being successful. He reported that he uses a one-page technology opportunity sheet that explains the technology, which he sends out to the company after an initial contact has been made. He reported that he follows-up with a more detailed interview with the company. The ERC currently brings in approximately $500,000 per year in membership fees, and all of the membership money goes to the Center. He reported that the annual membership fees are much greater than the annual royalties received from the licensing of ERC technologies.

Question Five

Do you usually grant exclusive licenses to companies who have sponsored research at the center?

The LO at the UM College of Engineering reported that when a company

sponsors research at the university, it typically receives a first option to license the technology. The companies do not receive an exclusive license, but they have the opportunity to negotiate for one, and there are windows of opportunity that are within the research contract that are explained to the industrial personnel. He reported that some companies want all of the IP, but it is unlikely that they will receive it. He reported that if a company were to offer a sizeable research project, the company should receive exclusivity immediately, but it currently does not exist at the UM.

The LO from MSU reported that if an invention was developed through Center research a company was funding, the company could receive an option to exclusively license the invention. If a non-sponsored research invention came out of the Center, the university licensing office would try to offer a non-exclusive license to the company seeking the invention, and it would be specific for the technology, industry, and the market. The licensing office would prefer to license non-exclusive when possible, but if there is a sponsor of a research project that produced an invention, the office attempts to negotiate with a company for a field of use versus an exclusive license. The LO reported that there are some companies that refuse the non-exclusive, and the licensing office has to negotiate with the companies.

Question Six

Does granting an exclusive license improve your licensing results for ERC inventions?

The LO reported that the Center for WIMS has been in existence for four years. He claimed that the licensing of inventions has been successful because his office has

been flexible in negotiating with companies. He reported that his staff has been able to match the licensing structure to the needs of the companies, which has been the key to making the process successful. He reported that some companies did not license when they did not receive exclusivity, but there have been companies who have not needed exclusivity to license inventions.

The LO reported that for some biotech companies there are many factors that may influence the decision of the university. For example, the specific usage of the invention, or the funding from venture capitalists may be contingent upon the company receiving an exclusive license from the university.

The LO at MSU reported that some companies have refused the non-exclusive license, and the licensing office had to be open for negotiation. The LO reported that the non-exclusive license has been good for the university, but depending on the technology, a company may need exclusivity in order to license it.

Question Seven

What are the methods that the university uses to ripen technologies to make them more attractive to industry?

The LO at MSU reported that faculty have obtained gap money for ripening technologies from the State of Montana's Research and Commercialization Program. The university licensing office has used the federal Small Business Innovation Research (SBIR) Program, which assists in placing companies with faculty. The LO reported that it is better to have an external source of funding than from the university. With university money, many faculty are attempting to obtain the funding through proposals, and the

funding mainly goes for fundamental research.

The LO at the UM College of Engineering indicated that the College of Engineering has a competitive gap fund for the engineering faculty. He reported that a committee, composed of the Director of the Technology Transfer Office, and six faculty from the College of Engineering, select and fund 3-5 research projects per year. The funds are used to develop a commercial-ready prototype. He claimed the Center for WIMS has more gap funding to move research projects to industrial application or readiness than his licensing office.

The Corporate Survey

A corporate survey was distributed and collected from industrial members while they were attending technical meetings at the Centers. The survey was introduced and explained by the ILO from each ERC, and collected by the Center support staff, and ILO at each Center. The researcher of the case studies was present at the Technical Advisory Conference (TAC) at the Center for Biofilm Engineering (CBE) in July 2003, when the survey was distributed to the industrial members visiting the Center. The researcher of the comparative case study made contact with many of the industrial members, while attending the three-day conference, and answered only questions from the members about the importance of the ERC case study.

The corporate survey at the UM Center for WIMS was distributed and collected from Center industrial members attending the Industrial Advisory Board (IAB) meeting in October 2003. Since the researcher was not able to attend the conference, ILO of the Center

introduced, explained the importance of the survey to the attending industrial members, distributed, and collected the surveys from the industrial members. The researcher visited the UM Center for WIMS in November 2003, and collected the corporate survey from the ILO, interviewed the Center faculty, CD, ILO, LO, and collected the historical NSF-ERC site visit data.

Twelve industrial surveys were collected from a total of 28 industrial members attending the Technical Advisory Conference (TAC) meeting at MSU. Five industrial surveys were collected from the 17 industrial members attending the Industrial Advisory Board (IAB) meeting at the Center for WIMS. Thirteen questions were included in the survey for industrial members.

Question One

How was the contact between the Center and your company established?

Two industrial members from the Center for WIMS reported that alumni of the UM introduced them to the Center. Two industrial member reported that the initial contact was established when the ILO and a Center faculty visited the company, and made a presentation to the industrial personnel. One industrial member reported that the initial contact was from a Center faculty member that he had met at a conference.

Six industrial members from the Center for Biofilm Engineering (CBE) reported that the Center faculty had been the initial contact. One member reported that he was introduced to the Center faculty when they visited the company to make a presentation to industrial personnel. Two of the industrial members reported that their first contacts had been established by the Center Director, with one being at a conference, and the other

through previous consulting work with the Director.

One member claimed that he stumbled upon the Center while touring the MSU campus while visiting a relative. One industrial member reported first contact was through a new employee within his company, who has a continuing research relationship with one of the Center faculty. One industrial member reported that the initial contact was through the Center Web site. One industrial member claimed himself as the first contact, since he had been a former employee of an industrial member, had previously visited the Center, and encouraged his new employer who joined the Center.

Question Two

Who initiated the first contact between Center personnel and industry ?

Two industrial members of the Center for WIMS reported that the Center Director had been their initial contact. Two industrial members reported Center faculty as the initial contact, with one of contacts resulting from an on-going relationship with a faculty member. One of the industrial members reported that the ILO of the Center for WIMS had been the first contact.

Six industrial members of the Center for Biofilm Engineering (CBE) reported the Center faculty as their initial contact, and two industrial members claimed the Center Director. Four industrial members reported that the initial contacts were from industrial personnel. Of the four, two industrial members reported that they had initiated first contact with Center personnel. One member claimed that he had been a former employee of an industrial member of the Center, and has become employed with a different industrial member of the Center. One industrial member claimed that he found the Center

when visiting the Montana State University (MSU) campus with a relative. Two of the industrial members reported that an employee within their company established the first contact with Center personnel.

Question Three

Why did your company join the Center as an industrial member?

One industrial member of the Center for WIMS reported that their company joined to be associated with a leading R&D research Center. Two members reported that their companies joined to have access to Center technology, interest in Center research, and access to Center students and faculty. One industrial member reported that his company joined for the Center research. One member reported that their company joined to gain knowledge from the Center faculty on specific technologies, and to establish collaborative projects with the Center.

Ten of the industrial members reported that they joined the CBE for the knowledge they would gain from the Center research. Three of the ten industrial members claimed that the opportunity to perform collaborative research projects with the Center faculty was a large factor for their companies joining the Center. One industrial member reported that his company had joined to learn the latest technology in biofilm research, and to collaborate with Center faculty to bring Center technologies into their company. One industrial member reported that his large company joined because it has been advantageous for his company to have joint research participation, and discuss research projects with other industrial members.

Question Four

How can the Center personnel improve their marketing to prospective industrial members?

One industrial member of the Center for WIMS suggested using the existing members as ambassadors for the Center to improve Center marketing to prospective industrial members. One member reported that the Center could contact more R&D industrial personnel, and one member suggested using success stories as a marketing tool. Two of the surveys were left blank for question four.

One industrial member of the CBE at MSU recommended that Center personnel could improve their marketing by becoming a liaison for government regulators and the industrial members. One member reported that the Center should have a "members only" section on the Center Web site, which stresses applications, workshops, and solutions to biofilm problems of commercial relevance. One industrial member recommended contacting quality industrial organizations. One member claimed that advertising in scientific journals, and sending a cover letter and supporting material to industrial representatives of the prospective companies. One industrial member reported that the Center could perform research that was closer to industrial applications. Five industrial members recommended Center participation in major conferences of the targeted industries, and one member suggested that promoting the Center's research and capabilities at targeted trade shows could improve the marketing of the Center. One member reported that the Center could inform the companies about the Center's expertise in biofilm testing, and the Center could market and sell their biofilm testing programs.

Question Five

How can the Center improve and maintain your industrial membership?

Three industrial members of the Center for WIMS reported that joint publications with Center faculty, receiving monthly newsletters, and working with Center faculty to fund company projects by federal agencies were factors that assisted in maintaining their Center memberships.

Two industrial members recommended that an invitation from Center faculty to participate in collaborative projects with the faculty, and using the Center as a liaison between federal agencies and industry would be helpful in bringing the two parties together. One industrial member reported that the Center faculty and ILO could inform and advance the value of the CBE to upper management in the company. Two members suggested that the Center could stress training, applications, and solutions to biofilm problems of commercial relevance, and the benefits of Center membership. One member recommended that the Center could educate industrial personnel, and collaborate with regulatory agencies to develop policies, guidance, and methods for testing. One industrial member reported that the opportunity to fund small projects for students has been very attractive for his company. One industrial member indicated that the Center personnel could keep the industrial member informed of current faculty research pertaining to their company's needs. One industrial member reported that the Center should continue to provide educational programs related to biofilm and water delivery systems.

One member reported that the Center personnel could maintain industrial memberships by performing small projects without extra cost, conducting TAC meetings

with subjects that are clearly expressed, and provide more presentations of new technologies. Additionally, the member suggested that center personnel could inform industrial personnel of the expertise available to them at the Center, and that the Center should conduct research projects with his company at a reasonable cost.

Question Six

Are you satisfied with your investment in membership to the ERC?

All five industrial members of the Center for WIMS reported positive satisfaction in their company's investment in the Center. Nine of the industrial members of the CBE reported positive industrial satisfaction for their membership to the Center, and three of the industrial members did not answer the question.

Question Seven

What benefits of the Center membership are valued by your company?

One industrial member from the CBE reported that collaborative research, the Center personnel, quality of the undergraduate and graduate students, and the quality and enthusiasm of the Center faculty are valued by his company. One industrial member reported that the expertise of the Center faculty, staff, and students, the high quality facilities, and the testing capabilities of the Center are valued by their company. One industrial member indicated that the conferences, publications, and the numerous opportunities for Center research are the benefits that are valued by his company. One industrial member claimed that the Center educational programs, and their application to medical devices. One industrial member claimed that Center basic research, access to

Center faculty, and discussions about their company problems with the Center faculty were benefits valued by his company. One industrial member indicated that interaction with the Center faculty and visiting scientists, and the opportunities to fund small projects were important for his company. One industrial member reported that discussions with Center faculty about techniques, research methods, and their company's research needs were benefits of their membership in the CBE.

One industrial member reported the faculty accessibility and their desire to work with industry, the semi-annual TAC meetings, Center research presentations, and the flexibility of research projects with the Center faculty were important benefits of Center membership. One industrial member reported that the interactions and assistance of the Center faculty and staff were extremely important to his company. One industrial member reported that the Undergraduate Visiting Student Program (REU) program, contacts with the Center faculty, and the testing lab were important benefits of Center membership.

At the Center for WIMS an industrial member reported that his company values Center research and equipment, and one industrial member reported that his interactions with the students are a valued aspect for his company. One member claimed the Center research projects, and one member reported a specific technology that has been beneficial for their company. One industrial member reported that the interactions with the Center faculty and their relevant Center technologies have been valued aspects for his company.

Question Eight

What Center aspects, if any, have not met your company's expectations?

One industrial member of the Center for WIMS reported that his company wants more opportunities to perform joint research projects, and publish the research results with Center faculty. One industrial member from the CBE reported that his company would like to see Center research move closer to industrial applications.

Question Nine

What methods are used within your company to find university research that will meet your company's needs?

Two industrial members from the CBE reported that their company uses canvassing, and attending presentations at conferences. Four industrial members reported that their methods are going to conferences, reading the publications, and canvassing. One member reported that when there has been a lack of in-house research capability, his company has sought assistance from quality research Centers. Four of the industrial members reported that their company's methods are going to presentations at conferences and reading publications.

One industrial member reported that his company finds university research through industrial and academic personnel contacts. One industrial member reported that his company's methods have been through the contacts of academic researchers at conferences, referrals from experts, and reading publications. He reported that the quality and prestige of the research lab, the relevance and cost of the Center research, and the faculty communication skills are factors that his company compares before joining a research Center. Some additional methods for companies seeking university research have been through Society memberships, trade publications, Web sites, and through

workshops.

One industrial member of the Center for WIMS reported that they have used German research centers in addition to the Center for WIMS. One industrial member reported that all research proposals in his company must be submitted to in-house funding committees when seeking university research. One industrial member reported that his company representatives attend conferences for seeking university research that best matches their company's needs. One industrial member reported that attendance at conferences, publications, and canvassing are methods that his company has used when seeking university research.

Question Ten

How often are the methods employed in seeking out university research?

The industrial members at the Center for WIMS reported that the methods were employed annually, monthly, daily, and when needed in seeking university research.

Two industrial members of the CBE reported that their methods were employed quarterly. Two industrial members reported that methods were used daily in seeking out university research. One industrial member reported that methods were used annually, and one industrial member reported that methods were employed when necessary. One industrial member claimed that methods were employed monthly at his company. Two industrial members indicated that the methods were used daily, when opportunities arose, and with no particular process. One industrial member suggested that it depended upon their company's budget, and that it was more financially favorable in the first part of the year for industrial personnel to travel to conferences. One industrial member reported

that the methods were performed weekly at his company. One industrial member claimed that the methods were employed at variable times, and that he personally reviews scientific literature through Internet searches on a weekly basis.

Question Eleven

What methods in seeking university research provided your company with the best results?

Only one industrial member from the Center for WIMS responded to question eleven, and he reported that working closely with universities and the Centers has provided his company with the best results.

One industrial member from the CBE at MSU, reported that the methods that have provided his company with the best results were meetings and person-to-person interactions, which have led to further contacts and discussions, and eventually to collaborations. One industrial member misinterpreted the question, and reported that an ERC has provided his company with the best results through the Center Web site, which informed him of Center testing capabilities. He reported that the Web site should inform viewers of the costs for various types of research.

Three industrial members claimed that attendance at conferences and publications have provided the best results for their companies. One of the three members stated, that "some personnel in our company are more aggressive in surveying literature than others. For those that are less involved in the literature review, attendance at presentations and conferences are more important. For me personally, they are equally important." One industrial member reported that referrals provided his company with the best results for

finding university research. One industrial member claimed that presentations at conferences provided the best results for his company. One industrial member reported that attendance at presentations and conferences, publications, and canvassing have provided his company with best results. One member indicated that attendance at presentations and workshops provided the best results for his company. One industrial member reported the best methods have been from research organizations and referrals from experts.

Question Twelve

What factors within the university may inhibit the research partnership of an ERC and your company?

Only two industrial members from the Center for WIMS responded to question twelve. One industrial member reported that no factors within the university have inhibited their research partnership with the ERC. One industrial member reported that ownership issues, publishing, royalty rates, and bureaucracy may eventually inhibit their partnership between the ERC and the company.

One industrial member from the CBE at MSU reported that publishing and royalty issues have been challenges for them when partnering with an ERC. One industrial member claimed that Intellectual Property (IP) ownership issues, and costs for performing testing or research may inhibit their partnership with the ERC. One industrial member claimed that diminishing research funding within the university may eventually inhibit research partnerships with ERCs. One industrial member reported that specific timeframes may eventually inhibit the partnership of the ERC and his company. One

industrial member claimed that regulations and policies within the university are factors that may inhibit his company from partnering with an ERC. One industrial member reported that ownership and royalty rates may inhibit their partnership with an ERC, and one industrial member claimed that his company has no problems in their research relationships with Centers. One industrial member reported that royalty rates and publication ownership are issues that may inhibit their research partnering with an ERC. One industrial member claimed that ownership, publishing issues, royalty rates, and university bureaucracy may inhibit their research partnerships with ERCs. One industrial member reported that the university's inability to react to a spontaneous problem may inhibit their partnership with an ERC. One industrial member indicated that the ownership of patents, the cost of research, and publishing issues are factors within the university that may inhibit his company from partnering with an ERC.

Question Thirteen

Question thirteen of the corporate survey asked the industrial members for the importance of specified Center benefits for their companies. The members selected from a numbered 1-5 scale, with 1 being very important, 2 being important, 3 being moderately important, 4 being somewhat important, and 5 being low importance. The final sub-question, question (13G), provided the industrial members the opportunity to add additional benefits, and to make additional comments.

Question Thirteen A

How important is the ability to participate in additional jointly sponsored research projects?

Four industrial members of the Center for WIMS reported very important, and one industrial member reported extremely important, for the ability to participate in additional jointly sponsored research projects. Six industrial members of the Center for Biofilm Engineering at MSU reported extremely important, three members claimed very important, one member claimed moderately important, and one industrial member reported somewhat important for the opportunity to participate in additional jointly sponsored research projects.

Question Thirteen B

How important is the opportunity to sponsor proprietary research?

Three industrial members of the University of Michigan Center for WIMS reported moderately important, and two members reported very important for the opportunity to sponsor proprietary research.

Five industrial members of the CBE at MSU reported extremely important, three members reported very important, two members reported moderately important, and one industrial member reported low importance for the opportunity to sponsor proprietary research.

Question Thirteen C

How important is direct access to Center graduates?

Two industrial members from the Center for WIMS indicated extremely important, one member claimed very important, and two industrial members reported somewhat important for the access to Center graduates. For question thirteen C, two

industrial members of the CBE at MSU claimed very important, three members claimed moderately important, four industrial members reported somewhat important, and two industrial members claimed low importance for direct access to Center graduates for their companies. One of the industrial member's who claimed low importance, reported that his company only hires experienced expatriates for his international company.

Question Thirteen D

How important to your company are research meetings with the Center faculty?

Three industrial members of the Center for WIMS claimed very important, one member claimed extremely important, and one industrial member reported moderately important for research meetings with Center faculty.

Seven industrial members of the Center for Biofilm Engineering at MSU reported extremely important, two members claimed very important, and three industrial members reported moderately important for research meetings with Center faculty for their companies.

Question Thirteen E

How important to your company are the Center workshops?

Three industrial members of the Center for WIMS reported very important, and two members claimed moderately important for workshops for their industrial companies. Four industrial members of the Center for Biofilm Engineering reported extremely important, four members claimed very important, two members reported moderately important, and one industrial member reported somewhat important for

workshops.

Question Thirteen F

How important to your company are in-house training options?

Three industrial members of the Center for WIMS claimed moderately important for in-house training options, one member claimed very important, and one industrial member reported somewhat important. Three industrial members of the Center for Biofilm Engineering reported extremely important, four members claimed very important, two members reported moderately important, and two industrial members reported low importance for in-house training options for their companies.

Question Thirteen G

The last question in the corporate survey was listed as “Other, please explain.” This was to provide the industrial member the opportunity to express an important ERC benefit for their company that was not listed for Question Thirteen.

Two industrial members of the UM Center for WIMS reported extremely important for advising and consulting, and for the exposure to new ideas. Four industrial members of the CBE at MSU explained important benefits for their companies as a result of Center membership. One industrial member reported extremely important, and reported that sponsored non-proprietary undergraduate research projects are extremely important to his company. One industrial member claimed that direct access to Center faculty with specific expertise has been very important for his company. One industrial member did not report a number in the survey, but reported that contact with Center

faculty for advice on general research was very important to his company. One industrial member did not report a number for the survey, but reported that it has been useful to meet with Center faculty to help establish acceptable test methods.

NSF Site Visit Documents

The potential life-cycle of an Engineering Research Center (ERC) under the NSF support has been 11 years, with an ERC's progress and plans assessed annually by the NSF, with major renewal reviews conducted during the third and sixth years of operation. The NSF site visit is an important milestone in the assessment of the progress of the ERC toward its goals. The site visit report is an important document that records the collective opinions and judgments of an NSF review team, and has a significant impact on the decision for continuing the NSF award in subsequent years. The researcher reviewed the NSF site visit historical reports from the CBE at Montana State University, and the UM Center for WIMS. The researcher reviewed the third, sixth, and ninth year site reviews for the CBE, and the third year review for the UM Center for WIMS, since the Center for WIMS is in their fourth year of funding with the NSF.

The purpose of the third and sixth year renewal reviews are to determine whether an ERC will continue for the next five years under NSF support or whether the ERC will undergo a two-year phase-down of NSF support because the ERC failed to receive renewal recommendations.

The University of Michigan Center
for Wireless Integrated Micro Systems

The Center for WIMS Third-Year Review

The WIMS ERC successfully passed its third year review by the NSF in October 2003, and the site visit committee unanimously recommended that the Center for WIMS be funded for another five years. In addition, the NSF committee unanimously recommended that the Center for WIMS funding level be increased. The NSF site review committee reported that there has been continued satisfaction of industrial members and membership has been sustained in a difficult economic climate. Two of the three members that left the Center did so for strategic reasons, not dissatisfaction, and the third left for economic reasons, but intends to rejoin in the near future.

The Industrial Advisory Board (IAB) members expressed a high degree of satisfaction with the strategic direction of the Center, and with the degree to which their individual objectives for membership were being served. Recruiting of students, Intellectual Property (IP) advantage, and technology awareness emerged as the benefits of Center membership. Additionally, access to Center faculty for consultation and networking within the IAB community were reported as important. The industrial members were participating to the best of their abilities in the Center, but were restrained from a desired higher level of participation by their need to focus on near-term corporate objectives. An on-site presence was frequently reported to be the preferred mode of enhanced participation. Although the IAB members found the ERC to be of compelling value, and paid for itself in one or two years time, an increase above the $50,000 annual

membership was viewed universally as unacceptable.

IP issues, such as non-disclosure agreement concerns, access to technology, and collaborative IP agreements did not surface as prolonged discussion topics, as opposed in other years, an indicator that the solutions previously identified are satisfactory. When polled, the Center members universally valued students with strong systems backgrounds, and the quality of graduate students was applauded. The members were less clear as to whether a sacrifice in technical depth would justify systems experience. The evaluation committee strongly recommended that the solution should be to motivate thrust research projects in the context of testbed-inspired systems. The system attitude needs to be ingrained into the thrust leaders and students to a greater extent than what currently exists. One suggestion was to investigate whether a Masters Degree program in System Engineering could achieve the desired combination of analytic systems ability and technical depth for new employees.

There were a few issues that the NSF review committee reported that the Center should continue to improve for the industrial members. First, approximately 40% of the IAB membership is composed of early stage companies almost exclusively related to faculty from the ERC. It is hoped that the early stage companies achieve sustainable revenue, and become both financial and intellectual contributors to the ERC. Second, the industry is engaged in a general way with the ERC, but the industry has not found the key spokesperson to provide leadership to the ERC. Though this takes time, the ERC, management should work closely with the IAB to encourage a more active role in working with the ERC. Finally, an excellent opportunity for interaction and collaboration

has been the continued support and interaction with the ERC testbeds. It is essential that companies continue to provide staff and funding support to help mold the testbed activity.

Center operations appeared to be running smoothly for the industrial component. Formal meetings of the IAB have been conducted on a bi-yearly basis. Because of the strong technical participation of the partner universities in the ERC, the industrial members effectively interact with all three universities, but primarily through formal programs at the University of Michigan.

In summary, the members are highly satisfied, but were participating at levels below those initially anticipated by the industrial members and the ERC, mainly due to economic constraints. Access to well-trained students, particularly those skilled in systems integration, continued technical excellence in enabling technologies, and remote educational offerings are particularly valued. The review committee was concerned that the high level of satisfaction cannot be sustained if a low level of participation continues. It is urged that the ERC continue to challenge the members to fully participate in order to ensure a lasting relationship. Measures of this progress as well as knowledge and technology transfer should be defined and tracked.

The Center for WIMS

In 2000, the University of Michigan joined with Michigan State University and Michigan Technological University to form the Engineering Research Center for Wireless Integrated MicroSystems (WIMS). The University of Michigan Center for Wireless Integrated Microsystems (WIMS) is focused on miniature low-cost integrated

micro-systems capable of measuring or controlling a variety of physical parameters, interpreting the data, and communicating with a host system over a bi-directional wireless link. The Center for WIMS addresses the intersection of microelectronics, wireless communications, and micro-electromechanical systems (MEMS). The resulting devices are expected to become pervasive in society during the next two decades, extending the electronic connectivity now represented by personal communications and the worldwide web to information provided directly by or supplied to the environment. Such systems will provide button-sized information-gathering nodes for applications ranging from environmental monitoring to improved healthcare with wearable and implantable biomedical systems. They will consist of a power source, software, an embedded micro-controller, a hardwired or wireless interface to the external world, and front-end micro-instruments selected for the intended application. The Center for WIMS has been organized into four thrust areas, which include micro-power circuits, wireless interface, sensors and micro-instruments, and micro-packaging.

Solving societal problems requires that technical developments be applied in products. Thus technology transfer and industrial partnerships are critically important. An industrial partnership program at the Center involves leading companies in microelectronics, MEMS and wireless communications, including companies from the automotive, environmental, and medical fields. The companies participate in the Executive Committee and Industrial Advisory Board (IAB) of the Center, and help direct and determine policies both in education and research. Student scholarships, internships in industry, and visiting industrial positions at the university are being used to facilitate

technology transfer through personnel exchanges. Recognizing that the missing link in many technology transfer efforts is the ability to generate prototypes for evaluation by industry, the Center for WIMS has been dedicating both personnel and facilities to producing such devices, and ensuring that the results of its research are translated into products that benefit society.

The Center for WIMS industrial member distribution is composed of 48% small companies, 11% medium companies, and 41% large companies. The industrial member distribution for all ERCs is composed of small companies 24%, medium companies 11%, and large companies 65%.

The UM Center for WIMS involves faculty from most engineering disciplines as well as from computer science, chemistry, public health, and medicine. The efforts of faculty members are focused by the research testbeds. The Center Director and Deputy Director are from the University of Michigan, with Associate Directors from Michigan State University and Michigan Technological University. The personnel, together with the Administrative Director, the Associate Director for Industrial Programs, the Associate Director for Education, and the research thrust leaders, form the Management Committee for the Center. The Center Director reports directly to the Dean of Engineering at the University of Michigan.

The Center for WIMS involves 43 faculty, 202 students, 114 projects, and a combined budget of more than $14 million per year. The current industrial membership is composed of 17 companies, and the most recent strategy of the Industry Advisory Board (IAB) is to increase membership to 30 companies. The Center for WIMS had 157 third-

year publications, which includes 47 journal articles and 110 conference proceedings.

The Center for WIMS funding level for the fourth year is $3.8 million, and the NSF will add an additional $200,000 to support the involvement of more undergraduate minority students at the ERC. Partnerships are being explored with a number of minority-serving schools, including Howard, Tulane, Prairie View, and Puerto Rico-Mayaguez.

The Center for Biofilm Engineering at Montana State University

The ERC at Montana State University was originally called the Center for Interfacial Microbial Process Engineering, and was NSF funded from April 15, 1990 at a level of $7.4 million for the first five years. After the tragic death of Dr. Characklis in 1992, the CBE was almost dissolved by the NSF because of the importance of having a strong Center Director to recruit and maintain the industrial members. At that critical time, numerous industrial members went to Washington D.C., and convinced the NSF ERC Program administrators to continue to fund the Center.

Dr. William Costerton, an internationally recognized microbiologist from the University of Calgary was employed as the Center Director of the CBE. Dr. Costerton convinced biofilm researchers and industrial companies that were affiliated with the University of Calgary to join him at the CBE.

Dr. Costerton is one of the first proponents of the biofilm theory, and he has published more than 600 papers describing the biofilm mode of bacterial growth in numerous systems. One of Costerton’s scientific breakthroughs came in 1999 when he discovered that biofilms damage tissues primarily by triggering inflammation. He

suggested an innovative approach to treating chronic diseases by using immune modulators instead of antibiotics. Costerton claims that the antibiotics that have been designed to kill free-floating bacterial cells work poorly against cells growing in slime enclosed biofilms.

The ERC at MSU is the largest and most active biofilm Center in the world. The Center allows multi-disciplinary research teams to find solutions for industrially relevant biofilm problems, and potential uses for beneficial biofilms in waste disposal and bioremediation.

MSU has made a very strong commitment to the ERC, which is impressive when there have been difficult economic times in Montana. In response to recent budget cuts in higher education mandated by the State legislature, the University administration has repeatedly cited the ERC as the exemplary program on campus that should be supported and emulated. The President, Provost, and Vice President for Research all serve directly on the Center's Policy Advisory Board (PAC). The awareness and willingness of the university administrators to support and participate with the Center has been repeatedly confirmed. The support of the university to complete the construction of the $29 million Engineering and Physical Science building was completed among the numerous budget reductions by the State of Montana.

The Industrial Associates Program remains the primary vehicle for technology transfer at the CBE as well as a major source of operating funds for research. In 2003-2004, the CBE had 24 subscribing industrial members, whose annual dues contributed over $350,000 to CBE research operations. To expand the technology transfer efforts to

reach small businesses, the CBE began the Small Business Industrial Associate (SBIA) Program in early 2004. The SBIA program provides a mechanism for small businesses that sponsor CBE research to participate in the Industrial Associates Program at a rate discounted commensurately with the research sponsorship. The program has enlisted two memberships. Montana small businesses continue to take advantage of the CBE benefits through participation in the Montana Biofilm Research Consortium (MBRC). This is a program in its seventh year that helps Montana small businesses adopt technological advances and increase competitiveness.

The CBE faculty members make numerous visits each year to Center industrial members and to prospective members. The focus of the visits can be general biofilm education, and specific discussions related to product development or problem solving. The Center faculty offer feedback on R&D direction, marketing ideas, or strategic decisions. Basic and advanced biofilm methods workshops are held in conjunction with each Technical Advisory Conference (TAC). These one-day workshops provide a method for industrial associate members to stay current with the latest laboratory techniques for biofilm study.

CBE NSF Third Year Site Review

A third year renewal proposal submitted to the NSF reported the CBE industrial recruitment methods. The primary recruitment tool in securing new industrial members has been invitations to prospective companies to attend the Technical Advisory Conferences (TAC). Three primary sources of recruiting new industrial members are

from contacts from the CD, marketing through the Center newsletter, and regularly soliciting referrals from current industrial members.

Center marketing for new industrial members comprises the ILO contacting the prospective industrial member, providing Center information relating to the specific needs of the prospective member, and inviting the prospective member to visit the Center. Additionally, the prospective industrial member is invited to the Technical Advisory Conference (TAC) at MSU.

In the first three years of the Center, only three companies had left the program. The companies cited economic reasons for leaving rather than dissatisfaction. Over the first three years of the Center, the number of companies went from 14 to 18, and the annual membership fee increased from $10,000 to $15,000, and the industrial support doubled in three years.

The major mission of the ERC is to accomplish the transfer of knowledge and technology from academic research to industry, and eventually to the market. The most successful technology transfer occurs when there is direct personal contact between the Center faculty and industrial personnel. The ERC has evolved several mechanisms in which industry and academics are integrated in the transfer of knowledge. These include annual TAC meetings, strategic planning, education programs, and test-bed facilities.

Center interaction with industrial members occurs by way of the semi-annual Technical Advisory Conference (TAC) meetings. During TAC meetings, the CBE informs industry of research progress, receives guidance from industry, reviews existing and develops new research initiatives. In addition, linkages of students with industrial

mentors for guidance are created, as well as internships and prospective jobs. The Center strives to involve students as much as possible in the TAC meetings with many of the presentations being given by students.

Testbeds are physical facilities where one or more Research Initiatives are carried out. A Research Initiative is a set of projects that collectively address a critical R&D need of an industrial sector. The testbeds mimic field operations and they serve as vehicles for conducting Center research and learning in an industrially relevant environment. A testbed project serves as a hands-on meeting ground to strategically integrate key Center resources with company, government, and other resources for improved decision-making and innovation in biofilm technology.

The foundation of the CBE strategic partnerships is the current group of industrial members that participate under two types of partnerships. One type is where each company pays $20,000 per year for the Center membership fee. Each of these members has one designated representative that serves on the Center Technical Advisory Conference (TAC). In 1995, another category of industrial members was initiated under a program called the Montana Biofilm Research Consortium (MBRC). MBRC members are limited strictly to companies in Montana with gross revenue under $2,000,000. In recognition of the Montana Science and Technology Alliance, a $200,000 annual contribution to the Center has been made by the State of Montana. Currently, there is no subscription fee for the qualifying MBRC members, and there are six members at this level.

The top five benefits of industrial membership, as prioritized by the industrial

members are as follows: (1) Opportunity to sponsor and to recruit Center students; (2) Influence on Center research direction; (3) Technical Advisory Conference (TAC) meetings; (4) Integrating industrial relevancy into the Center Research Program; and (5) Micro-scale to macro-scale level of research.

The CBE strategic partnerships offer significant economic development opportunity for industrial and government members. The role of promoting economic development has been extended to directly impact the biotechnology community of Gallatin County, where MSU resides, and for the State of Montana. In addition, the MBRC allows local firms to benefit from the CBE links with larger companies outside Montana, and from the Center's ability to acquire research funds through joint proposals with four Montana companies under the MSU Center for Economic Renewal and Technology Transfer (CERTT) Biotechnology Program.

The CBE also works closely with the local community to promote technology development in the area. The Center participates in the Gallatin Valley Technology Alliance by making presentations on Center resources to the local biotechnology and environmental engineering industry. The Center also collaborates with the Gallatin Development Corporation in promoting development of environmental-technical companies. Biosurface Technologies is one company that was spun-off from the Center through license agreements on two biofilm monitoring technologies, which are the Biofilm Coupon and the Annular Reactor.

NSF Sixth Year Site Review

The NSF site report for the six-year review claimed that the Center has demonstrated a strong industrial development program. The Program has evolved over the history of the Center to the current Center Research Initiative Program, which comprises research partnerships, TAC meetings, and the establishment of field scale test beds. The NSF site team reported that the various industrial partnership activities are critical to the success and development of the CBE. The activities provide a continuous reference for industrial member needs and priorities, enlarge the technical expertise and conceptual framework for Center science, and provide a unique educational vehicle for Center students.

The site team reported that the industrial members commended the ILO for his management of the Center-industry relationships. There was general agreement among the site visit team that the Center had evolved an effective, balanced system for working with industry. The Center has increased their efforts to include smaller companies in their interactions, through the development of the Montana Biofilm Research Consortium.

NSF Ninth Year Site Review

The NSF nine-year site visit committee reported that the CBE had strong industrial support and university commitment. Their concerns were lack of support from the State of Montana, and their concern for self-sufficiency. The NSF review staff reported an opportunity existed for improving collaborations between Center personnel and industrial members for technology development to pre-commercialization.

The Center has continued to build its relationship with industry through the proliferation of its industrial program. At the time of the nine-year NSF site review, the Center had 28 industrial members who contributed to the program through the payment of a $20,000 per year membership fee. Industrial membership has continued to be a source of funding for the Center during their journey toward self-sufficiency, and the number of industrial members attracted has been expected to increase as the research in the Center expands into other disciplines, such as biomedical applications. The nine-year site review reported additional industrial interactions, and funding will be developed through the operation of the Biofilm Training Student Lab (BTSL), and compound screening laboratories.

The most apparent strength of the industrial member participation in the Center was the educational value derived from having graduate and undergraduate students working and interacting directly with industrial personnel on industry related projects. The approach exposed students to industrial thinking and problem solving, which informed them how industry views and approaches biofilm-related problems. The level of interaction was accentuated by the development of an Internet-based forum that allowed direct project oversight by the industrial members and the development of a strong line of communication between all of the parties involved. This level of industrial involvement with students has led to a very confident, qualified, experienced, and team-oriented group of students who are prepared to enter the work force upon completing their education at the CBE. Several industrial members have commented on the quality of the graduates and intern students that they had hired from the Center.

The NSF site review reported that the industrial members claimed that they are a part of the Center, even though they may not have as much control over the research efforts as they would like. The lack of research direction by industry was likely due to the diversity of the current industrial members. The industrial members appeared to appreciate the importance of the basic research being performed at the Center, and an understanding of the difficulty to perform such work in their corporate settings. The industrial members understood the importance of their contribution to the CBE, and appeared willing to continue their support if possible in their individual corporate settings.

The NSF nine-year site review reported that the marketing of the CBE to industry does not appear to be a focused or organized program. The review team expressed that a more focused effort would increase national awareness of the CBE and the Center's contribution to individual companies. The development of the CBE Web page and trade journal has helped to enhance CBE awareness, and the publication of a *Science Magazine* article on the importance of biofilms provided international exposure. The review team claimed that the creation and distribution of a marketing document to target specific industries would be especially effective following the publication of the Science Magazine article.

The industrial members reported concern about project management at the CBE, and the tendency of the Center faculty to overestimate their ability to complete projects within a stated time frame. A concern was reported from a few industrial members about the difficulty and time it took to execute contracts with the university and Center. The

industrial members cautioned about a tendency to over sell the Center's capabilities or technologies. The installation of a web-based project management and interaction system will aid both the industrial members and Center personnel in managing projects, and insuring the timely completion of projects and dissemination of knowledge.

Although the industrial members reported their support for the Center's focus on basic research, they also expressed concern regarding the Center's emphasis on the study of simple model systems. They expressed a need to evaluate more " real world" biofilm communities, and the need for performing fieldwork.

The industrial members reported concern about their continued ability to financially support the Center over the long term with the current economic situations for individual companies. Some industrial members reported that Center personnel should inform the members how involvement in the Center results in a competitive advantage for their companies. A concern was reported about the loss of Center funding, because of the dependence on one champion within a company. The champion needs to sell the CBE, and they tend to be researchers rather than corporate decision-makers. The site review committee recommended that Center personnel market the Center to upper management who make the financial decisions, and that the marketing method is extremely important as the CBE moves toward self-sufficiency.

The nine-year review reported that the CBE has established itself as a world leader in biofilm research, and has strengthened the Center's reputation throughout the period of NSF support. The Center has attracted a considerable number of industrial members that view the Center as a unique and indispensable resource for biofilm related

problems. In addition, the Center has developed many testing methods that most likely will become the generally accepted standard for biofilm related problems. The CBE has an excellent national and international reputation for its facilities and research personnel, and the Center outreach effort has been excellent. The Center has efficiently used the Internet technology to disseminate information and to stay in contact with the industrial members. A trade magazine has been established that is highly appreciated by the industrial members, and the magazine's nationwide circulation has further contributed to the visibility of the Center.

In recognition of the Center's emphasis on self-sufficiency, which was a result of the eventual phasing out of NSF funding, a Self-Sufficiency Task Force (SSTF) was established in 1999. The university has made a significant commitment of space to the CBE, and university administrators indicated that they would continue to honor the commitment in the future. The excellent research labs, student and research facilities, and faculty labs are of great importance to the continued productivity of the Center.

NSF Center funding will be replaced by an increased commitment from Montana State University. By year twelve, (2001), the university has provided 60% of the Center's operational costs, and to achieve the goal, the university has provided approximately $200,000 for student stipends, and has returned 50% of the indirect costs to the Center. The university commitments have been extremely important to the continued operation of the Center. Industrial support for Center operations has increased, and has been approximately $150,000 per year. Support from research grants and contracts have been expected to increase during the next two years, from the current $1.5 million to $3

million. The increase in grants and contracts should support faculty and student research activities, student stipends, faculty salaries, and the infrastructure needs of the Center's laboratories. Additionally, the return in indirect costs from these grants will support operational costs for the Center. Center faculty members have realized the need for increased funding from grants and contracts, and in response to this need have submitted numerous grants to the federal agencies. The weakness that was noted by the NSF was that the State of Montana has not continued an annual commitment of $200,000 that was originally made to the Center, and that the funding is clearly needed by the Center.

Summary - Montana State University, Center for Biofilm Engineering

Faculty Summary

The majority of the Center faculty at the CBE have engaged in consulting or research projects for industry prior to the companies joining the Center. Industrial personnel usually initiate the contact between industrial personnel and Center faculty. The faculty reported that industrial personnel find the Center faculty through the Internet, Center web site, publications, literature, referrals from other companies, the CD, the ILO, and from their presentations at technical conferences. An informal process exists whereby faculty members pass any industrial leads to the ILO upon their return from technical conferences, and whenever faculty are individually, contacted by industrial personnel who are interested in Center research.

Center faculty market the Center to industry through their web sites, presenting at technical conferences, conducting workshops at industrial sites and at the Center, visiting

industrial sites, faculty publications, and through freely distributing some of their technologies to industry and government agencies. In addition, a software package allows the Center staff to monitor Internet users that are visiting faculty web sites.

The best methods for building Center-industry partnerships are through having quality research, facilities, faculty, and students, listening to industrial personnel about their interests and needs, traveling to industrial sites, conducting workshops, inviting industrial personnel to visit the Center, targeting the right companies, and developing strong communication skills. Building a relationship with key industrial personnel to create a champion for the Center within the company is crucial to annually convincing upper management to approve the annual membership fee.

The CBE Center Director Summary

The CD is a key figure in building and maintaining Center-industry research partnerships. The CD at the CBE has published extensively, and travels continuously to international conferences presenting his professional papers, and promoting the Center. He claims the majority of the industrial leads for the Center, and forwards those leads to the ILO at the Center. The CD reported that the Center has approximately 15 patents that are collecting royalties annually for the university. Only two small companies have been spun-off from the Center research, and approximately ten technologies have been transferred to industrial companies. The CBE grants exclusive licenses for their inventions based on the amount of research funding that a company provides to the Center. The CD would rather receive research money than rely on the university patenting system. The CD has reported that the Center freely gives away much of their

technology to industry and federal agencies, and has not been successful in bringing royalties returns to the university. The CD has been successful in convincing university administrators the importance of the ERC, which has resulted in the Center receiving a better rate on indirect costs associated with industrial research at the Center. The CBE has established alliances with other universities, and with numerous federal agencies. The CD reported that the best marketing methods are to have excellent publications and presentations at technical conferences throughout the world. Other methods that are successful are the Center web site and faculty web sites. The type of companies that join the CBE has changed over the course of the Center history. In the earlier years, the Center membership was dominated by the oil sector, but it has changed with the medical and biotechnology sectors becoming the majority for the current membership.

CBE Industrial Liaison Officer Summary

The ILO from the CBE claims that the Center web site provides the greatest amount of leads for prospective industrial members, but the Center Director (CD) provides the best leads. In contrast the industrial members claimed that the Center faculty were the initial contacts, and only a few industrial members initiated the contact with Center personnel. The ILO reported that the most successful method for bringing in new industrial members has been the CD visiting companies, and making presentations. In addition, Center staff contact the industrial members competitors for memberships to the Center. The main strategy has been to seek companies that can benefit from Center research, and to target the right personnel to contact. In addition, the Center staff targets specific conferences that will be attended by industrial representatives and federal

representatives, and has the Center faculty attend the conferences to make their presentations. Cold calls and mass advertising have been methods that have failed in enlisting new members. The best method for maintaining industrial members has been to provide the members with value for their membership. The industrial representative needs to convince the company's upper management that the investment in Center membership is beneficial for the company, which is reflected in delivering value to the company. The ILO reported that the main cause for members leaving the company have been the loss of the industrial champion due to retirement or transfer in the company.

MSU Technology Licensing Officer Summary

The LO from the CBE reported that the leads are revealed during the disclosure process with the inventor. He claimed that the inventor has provided the best leads for the licensing of inventions. The university has allowed no indirect costs to be taken from the industrial funds for the Center, which has allowed all funds to go directly for Center research. Industrial members receive options on the licensing of the inventions when they sponsor research at the Center. The Center has a premier level membership, which allows 100% of the intellectual property to go to the company sponsoring the research. The best method for licensing inventions has been to acquire leads from the inventor, and from companies that have previously sponsored research at the Center. The LO claimed that the university has to be open to negotiations if the company needs an exclusive license for the technology. The LO reported that the Montana Research and Commercialization Program and the federal SBIR Program are used to attain gap money for the ripening of technologies.

CBE Industrial Member Summary

More than half of the industrial members from the CBE reported that the Center faculty initiated first contact between Center and industrial personnel. Other methods were through the CD, employees, and the Center web site. The majority of the industrial members joined the Center for the knowledge their companies would gain, and to perform collaborative research projects with Center faculty. Almost half of the industrial members reported that the Center should target specific conferences to improve their marketing of the Center to industry. Industrial members claimed that the Center could act as a liaison between the regulatory agencies and the industrial members, and conduct research that is industry applicable, which would improve and maintain their Center membership. Other members reported that small research projects for students, participation in collaborative research projects with Center faculty, and reasonable costs for company projects at the Center would maintain their membership at the Center. The majority of the industrial members are satisfied with their investment in membership at the ERC, but one member would like to see Center research move closer to industrial applications. The majority of the industrial members at the CBE claimed that the access to Center faculty was the most important benefit of their Center membership. Many of the industrial companies attend conferences, read publications, and canvas universities in order to find university technologies to lease for their companies. The additional methods for finding university technologies reported were through Society memberships, trade publications, Web sites, and through attending workshops. The best methods for finding university research were through attendance at conferences, reading publications, and

canvassing. Industrial members reported that publishing issues, royalty issues, IP ownership issues, university bureaucracy, the Center's inability to respond to a problem, and the cost of research were some of the reasons that may inhibit their companies from partnering with an ERC. Most of the industrial members indicated that it is extremely important for their companies to have the ability to participate in jointly sponsored research projects, and somewhat important for access to Center graduates. The opportunity to have research meetings with the Center faculty was extremely important for the majority of the members. The majority of the members reported that is was extremely to very important for their companies to participate in workshops, and the majority of the industrial members claimed that it was extremely to very important for the opportunity for in-house training.

CBE-NSF Third Year Site Review Document Summary

The site review team reported that the primary recruiting method for bringing in new industrial members has been through invitations to the TAC for the prospective companies. The primary sources of recruiting are from contacts from contacts from the CD, marketing through the Center newsletter, and soliciting referrals from current industrial members. The most successful technology transfer occurs when there is direct personal contact between the Center faculty and industrial personnel. The Center interactions are mainly through the semi-annual TAC meetings. The site review committee reported the prioritized top five benefits of Center membership by the industrial members. The members claimed that the opportunity to sponsor and recruit Center students, influence on Center research, Technical Advisory Conference meetings,

integrating relevancy into the Center Research Program, and micro-scale to macro-scale level of research.

CBE-NSF Sixth Year Site Review Document Summary

The site review team reported that the CBE has developed a strong industrial development program that has evolved into the Center Research Initiative Program. The program is comprised of research partnerships, TAC meetings, and test beds. The Center has increased their efforts for including small companies, through the development of the Montana Biofilm research Consortium.

CBE-NSF Nine Year Site Review Document Summary

The NSF site review team reported that the CBE had strong industrial support and university commitment. At this time the committee was concerned about the lack of support from the State of Montana, and for the Center's self-sufficiency. The Center has continued to build a relationship with industrial members, and has 28 industrial members. The team reported that additional industrial interactions will be developed through the operation of the Biofilm Training Student Lab (BTSL). In addition, a Web-based project management and interaction system will aid industrial and Center personnel in managing projects, which will insure the timely completion of joint projects. The team reported that the strength of the industrial member participation in the Center was reflected in the educational value received through the students and industrial personnel working on joint research projects. The participation led to the development of an Internet forum for direct project oversight by the industrial members.

The NSF site review committee reported that the marketing of the Center to industry was not a focused or organized program. The review team reported that a more focused effort would increase national awareness of the CBE, and the Center's contribution to individual companies. The review team reported that the creation and distribution of a marketing document to target specific industries would be very effective.

Industrial members reported concern about the difficulty and time it took to execute contracts with the university and Center. In addition, members were concerned about the tendency of Center faculty to overestimate their ability to complete projects within a stated time, and the tendency to over sell the Center's capabilities and technologies. The industrial members claimed that the CBE staff should market the Center to upper management within the companies. The industrial members are concerned about the financial situations within their companies, and that Center personnel should inform the members how involvement in the Center results in competitive advantage for their companies. The committee reported that the Center has developed testing methods that have become the accepted standard for biofilm related problems, and has increased their national and international reputation because of their facilities and research personnel. The Center has used the Internet to disseminate information and to maintain their contact with industrial members. A trade magazine was established and has contributed to a higher visibility of the Center, and a self-sufficiency task was created in anticipation of the phasing out of NSF funding. On addition, the university has made a facility commitment to the CBE, and indicated that 50% of the indirect costs would be returned to the Center, and that the university would provide

$200,000 for student stipends. The NSF site team reported that the university commitments have been extremely important to the continued operation of the CBE.

The University of Michigan Center for Wireless Integrated MicroSystems

Center Faculty Summary

The Center for WIMS has been conducting quality research for the past two decades before becoming an NSF ERC. Therefore, the industrial personnel are very familiar with the Center faculty, and usually initiate the first contact between the company and Center faculty. The Center faculty have usually performed consulting or research projects prior to the company joining the Center, or the company has joined the Center after the researcher has completed the project for the company. The thrust leaders of the Center meet each week with the CD, ILO, and administrative staff to be informed of the status for each prospective and current member of the Center. The Center faculty's industrial leads are passed on to the ILO at this time, and usually occur because the faculty or their students have made a presentation at a conference. The Center faculty market the Center to industry through attending conferences and making presentations, their publications, and visiting company sites. In addition, the Center's Industrial Speaker Series and Masters Program in Integrated MicroSystems, which is programmed for returning industrial personnel, has contributed to establishing strong relationships with industry. The University of Michigan alumni advocacy efforts, and the university's international reputation for delivering world-class research results, has contributed to having UM alumni, who are currently employed with corporations, seeking university

inventions and research opportunities for their companies.

The Center faculty reported that the best methods for building industry-ERC partnerships are through a strong ILO who communicates often and well with the industrial members. The Center faculty claimed that they respond to all inquiries from industrial personnel, travel to company sites, keep faculty and Center web sites current, and provide presentations for the industrial personnel. Keeping the industrial members involved in collaborative research projects with faculty is crucial to maintaining them as members. The Center administrative weekly meetings to determine the status of all prospective and current members, has assisted in keeping all Center personnel informed and aware of the strategies for bringing in additional corporate sponsors. The Center for WIMS superior commercial grade laboratories, and qualified staff contribute to maintaining the members of the Center. The Industrial Advisory Board (IAB) meetings have contributed to maintaining industrial members. In addition, each faculty member is assigned a company, and is responsible for visiting the company, and keeping the industrial personnel informed of the Center research, and involved in the Center activities. Numerous faculty reported that not maintaining personal interactions with prospective or current members will result in losing industrial memberships. Cold calls, mass mailings, and sending literature without personal interactions with industrial personnel are methods for failure. The students that are trained at the Center for WIMS are systems trained and in demand by many companies. The majority of the Center students become employed by the industrial members, and a few have become eventually become Center champions. The students are a benefit of Center membership for the

industrial members, but not the primary reason the companies join the Center.

Center for WIMS Center Director Summary

The culmination of three Michigan universities faculties provided the initial leads for bringing in the first group of industrial members for the Center for WIMS. The CD reported that the faculty had numerous previous contacts with many of the industrial personnel because they had hired their former students. The CD for the Center at WIMS reported that acquires approximately 50% of the leads, and the faculty acquires 50%.The Center uses an informal system, where the Center faculty informs the ILO of the industrial contacts. The ILO sends the prospective members information on the Center, and the Industrial Program, and the Annual Report. The weekly staff meetings allow Center personnel to be informed of the current leads, and status of the prospective and current members. The Center has filed for approximately 20-25 patents, and 3-4 companies have been spun-off from the Center, with all of the companies joining as members. The CD reported that the Center has transferred a few technologies to industry, but the Center is only in the fourth year of existence, and has transferred approximately six technologies to industry before the Center became affiliated with the NSF. The CD reported that the UM technology transfer policies allow exclusive licenses, but only for field of use, and others have to be negotiated with the UM technology transfer staff. The CD articulates his vision of the ERC to university personnel, Center staff, students, industry, NSF, and all Center visitors. The UM has been very supportive of the ERC, and uses the prestige of the Center in their marketing to donors of the university. The UM Center for WIMS has established alliances with 6-7 other universities. Additionally, the

Center has alliances with minority-serving universities with the intention of increasing the diversity of the Center. The Center has alliances with many federal agencies, such as DARPA, NIH, NIOSH, and the Homeland Security Agency. The CD reported that the best methods for building Center-industry partnerships are through direct personal contacts with the industrial personnel, a shared vision, among Center and industrial personnel, and the partnerships have to begin early and all personnel must work together for a project to succeed. The CD and the ILO travel together extensively, and make presentations at conferences, attend workshops, and visit company sites. The CD claimed that cold calls and guessing which companies are interested in Center research are methods that are not successful. The CD reported that attendance at the IAB meetings has increased because of a better format was introduced for the conferences. The meetings consist of research overviews by thrust leaders and poster sessions. He claims that having personnel networking and walking throughout the conference facilities has improved the IAB meetings.

Center for WIMS Industrial Liaison Officer Summary

The ILO reported that he examines the interest of many prospective companies, and then initiates relationships with key industrial personnel. He additionally attends many conferences, and meets many industrial personnel at technical shows. He reported that the companies are interested in the IP, faculty, and students at the Center. The ILO claimed that the Center faculty thrust leaders and College of Engineering Corporate Relations personnel are responsible for generating the most leads for industrial memberships. He indicated that the Center faculty pass business cards, names, and all

industrial contacts to the Center ILO. The ILO reported that the industrial mission is in contrast with what the NSF seeks in an NSF-ERC. The ILO reported that the NSF should educate companies to the advantages of an ERC membership.

No patents have been issued, but the Center has numerous provisional patents, and many of them will eventually be converted to utility patents. The ILO reported that one technology has been transferred, and the university has granted a few exclusive licenses, but no companies have withdrawn from the Center because an exclusive was withheld. He reported that personal contacts with the industrial personnel, has been the most successful method for the enlistment of industrial members. In addition, the ILO reported that conversing in one-on-one interactions with industrial personnel, listening to their particular company needs, and addressing how the Center faculty can solve their company's problems have been successful methods. The ILO claimed that the Center strategy for recruiting industrial members has been to increase their personal interactions with companies through the Center and the university alumni program. The Center strategy has been to interact with alumni and industrial personnel that visit the campus that have an interest in Center research. In addition, Center personnel attend targeted conferences and shows to present their Center research. Another strategy is to find numerous upper level industrial personnel that make the financial decisions, which effect Center memberships for their company. Cold calls and mass advertising are the least effective methods for bringing in industrial members. The best methods for enlisting industrial members have been through personal contact between Center faculty and the industrial personnel. The contacts consist of Center faculty visiting industrial sites, and

the industrial personnel visiting the Center, through invitation, to attend the IAB meetings, or within the Industrial Speakers program. In addition, the Industrial Resident Program allows companies to send their personnel to the Center for a year. A faculty member is assigned each company, and is responsible for informing the company of the Center research, interacting with the industrial personnel to determine company needs and problem areas, and finding a remedy for those problems. Changes in management, financial constraints, and the champion being reassigned or transferred are reasons for industrial members not renewing their Center membership.

University of Michigan - University Licensing Officer Summary

The LO at the University of Michigan (UM) College of Engineering reported that he asks the Center faculty and Center ILO for leads. He additionally obtains his leads through the disclosure process with the inventor, and through marketing research and patent searches. Low membership fees with the same benefits as the larger companies, has allowed the smaller Michigan companies to maintain their Center memberships. He reported that the UM has not been very flexible in the negotiations of the IP with industry, but the university has maintained long-term relationships with industry. The LO reported that the best methods for the marketing of Center inventions have been the IAB meetings, and Center faculty making presentations at the meetings. Other methods are the Center faculty making presentations at conferences, patent searches, and marketing multiple inventions in package to industry. He claimed that it is necessary to make quick, tight, and excellent presentations to the right personnel. He reported that he sends a one page technology opportunity sheet to the company after initial contact has been made,

and follows-up with a detailed interview with the company. Unsuccessful methods were making cold calls, and using local consulting companies. He reported that when a company sponsors research at the center for WIMS, the company receives a first option to license the technology, but not an exclusive license. The company has the opportunity to negotiate with the university for an exclusive license, but will probably not receive it. The LO reported that his office has been flexible in negotiating with companies for the IP. He claims that matching the licensing structure to the needs of the companies has been important for making the licensing process successful. He reported that some companies did not license when they did not receive exclusivity. The College of Engineering has a competitive gap fund for the ripening of technologies, but he reported that the Center for WIMS has more gap funding available than the licensing office.

Center for WIMS Corporate Survey Summary

The contact between Center personnel and industrial personnel was established by UM alumni and Center faculty. The industrial members reported that the CD, ILO, and Center faculty initiated the first contact between the two parties. The majority of the industrial members joined to have access to Center technologies, knowledge, and access to Center faculty and students. The industrial members reported that the Center staff could use existing industrial members, and success stories to improve their marketing of the Center to prospective industrial members. The members claimed that joint publications with the Center faculty, monthly newsletters, and working with federal agencies to have company projects funded would improve and maintain their Center memberships. All Center for WIMS industrial personnel reported that they are satisfied

with their investment in the ERC. Industrial members claimed that the Center research, equipment, students, research projects, and technologies are the benefits most valued by their companies. Only one industrial member claimed dissatisfaction with not being provided with more opportunities to perform joint research projects and publish results with the Center faculty. The industrial members reported that attending conferences, reading publications, and canvassing are methods that their companies use in finding university research. One industrial member reported that working closely with Center faculty has provided his company with the best results, and one member reported that IP ownership issues, royalty rates, and university bureaucracy may eventually inhibit their partnership with the Center.

The survey asked the respondents for the importance of particular Center benefits. The majority of the members reported that it was very important for the ability to participate in jointly sponsored research projects at the Center for WIMS. The majority of the industrial members claimed it was moderately to very important for the opportunity to sponsor proprietary research at the Center. The members claimed very important to somewhat important in having direct access to Center graduates. The industrial members claimed it was extremely important to moderately important for having research meetings with Center faculty, with the majority claiming that it was a very important benefit for their companies. The majority of the members reported that it was very important to have Center workshops, and the majority claimed it was moderately important to have in-house training options. Two members reported that the advising, consulting, and exposure to new ideas were extremely important benefits of Center membership.

UM Center for WIMS-NSF Third Year Site Review Document Summary

The IAB reported that the industrial members were particularly pleased with the recruitment of Center students, intellectual property advantage, technology awareness, access to Center faculty for consulting, and networking within the IAB community as benefits of Center membership. The members reported that they value quality students with strong systems backgrounds. The NSF review committee reported that the industrial members are highly satisfied, but are participating at levels below those initially anticipated by the industrial members. The committee reported that the Center staff should challenge the members to fully participate in Center activities in order to insure the Center-industry relationship.

CHAPTER 5

CONCLUSION OF THE CASE STUDIES

This chapter presents the conclusions of the comparative case study, and reflects how the results of the face-to-face interviews, the corporate survey, and the NSF-ERC documents may affect the building and maintaining of ERC-industry research partnerships, and policies within the university, the ERCs, industry, and the NSF. The conclusions are drawn from the responses of the participants in the interviews and surveys, the NSF-ERC documents, and from the current policies in place at the ERC's, the universities, industry, and the NSF.

The conclusions are presented in the identical sequence as within Chapter Four, but without the questions preceding the conclusions, and are within sections by the type of methodology used for the case studies. The section begins with conclusions drawn from the face-to-face interviews, followed by the industrial survey, and follow with the conclusions from the NSF-ERC site visit documents. A following section provides the recommendations based on the case studies for ERCs, universities, the NSF, and industry. The final section presents the recommendations for future research.

Conclusions from the Interviews with the Center Faculty

From the responses of Center faculties from the Center for Biofilm Engineering (CBE) and the University of Michigan (UM) Center for WIMS, consulting and

engagement of research projects by ERC faculty for industrial companies has provided an opportunity for the enlistment of industrial companies to an ERC. These activities are part of the courtship of not only bringing in industrial members, but as opportunities for the Centers to bring in additional revenue for sponsored research. Many industrial companies engage in sponsored research or have testing conducted with ERCs without joining a Center. For instance, the CBE has attained its largest profit margins from research testing projects with industry. Some of the companies have joined the Center after receiving successful results from the testing projects.

In the majority of the interviews of the faculty from both Centers, industrial personnel were reported to be the main initiators of contact between the Center and industry, and the Center Director was reported as an additional initiator of contacts at the CBE. There was variation in the opinions among the faculty of how industry became aware of them. These consisted of the Internet, Center web site, publications, conferences, company site visits, Technical Advisory Conference (TAC) or Industrial Advisory Board (IAB) meetings at the ERCs, and referrals from other companies.

The Center for WIMS had been conducting research for the past two decades before becoming an ERC, which has enabled industrial personnel to become very familiar with the Center for WIMS faculty. In contrast, the CBE has been in existence for fourteen years, but the Center Director has published over 600 papers, and travels throughout the world marketing the Center.

The CD reported that he generates approximately 50% of the leads, while the Center faculty provide the other 50%. The industrial members reported that industrial

representatives became familiar with the Center faculty through research conferences and publications. Their interactions and familiarity with the faculty assisted in building the relationship. Industrial representatives reported that the Center faculty and CD from the CBE are the initial contacts. The largest sources of leads that are passed on to the ILO are from the Center faculty, which are accumulated through attendance at conferences by faculty and industrial representatives. The ILO from the CBE reported that the faculty may provide the most leads, but the CBE Center Director (CD) provides the best leads for bringing in new industrial members to the Center.

The results of the Center faculty survey revealed that their main method for marketing of the Center to industry is through their attendance and presenting at conferences, and their publications. These practices have exposed their research to industry, and enables industrial representatives attending the conferences to identify a particular faculty member, and associate the presenter of a scientific paper with someone who is affiliated with an ERC. The interested industrial prospect may initiate a direct contact with the faculty member at the conference or contact them through email or phone. Additional methods of marketing by faculty members are through web sites, company site visits, consulting, and workshops.

The University of Michigan (UM) Center for Wireless Integrated MicroSystems (WIMS) additionally, promotes their Center through their Industrial Speaker Seminar Series, and a Masters of Engineering Program, which is a program for current industrial personnel choosing to return to school on a part-time basis. In addition, a Resident Engineer Program allows industrial personnel access university laboratories, faculty, and

students for $60,000 per individual. The three Programs provide opportunities for Center and industrial personnel to interact and become more familiar with Center facilities, faculty, students, and research. In addition, the University of Michigan alumni advocacy efforts, have introduced UM alumni that are employed by industry to ERC personnel. The thrust leaders of each research group meet with the Center Director (CD), Industrial Liaison Officer (ILO), and administrative staff to discuss the status of the each prospective and current industrial member. Each Center faculty member is assigned a company and is responsible for informing the company of all Center research, visit company sites, and keep continual interactions with the member to insure that the company is satisfied with its membership.

Once the company has joined the Center, elicitation of the specific problem that each company is experiencing, and searching for solutions for their industrial problems is key to maintaining their annual membership to the Center. Since companies that join the ERCs are seeking to learn something that will help them in a financially beneficial way, the industrial representatives who visit the ERCs have to convince upper management annually, how their investment in the ERC is financially improving the company. If the Center faculty can provide specific information for the financial decision-maker, the company will most likely stay as an industrial member of the ERC. Any marketing method that does not involve personal interaction was reported as working the least. Other methods that have failed included mass mailings, cold calling, and sending literature without follow-up to the companies.

The industrial members reported that the access to Center students is one of the many benefits of membership in an ERC, and from the results of the interviews with Center faculty and the industrial survey, the students are used as a marketing method in building ERC-industry partnerships. The majority of graduating engineering students are employed by industry, but not all of the companies that employ them are members of an ERC. There are cases of former students eventually becoming industrial champions of the ERC within the corporation, and many of them returning to the Center conferences as the industrial representative for their companies. Additionally, there are cases where students have completed sponsored research projects for a company, and upon graduation, became an employee of the company.

Conclusions of the Center Directors

The Center Directors (CD) of the ERCs reported that publishing, having quality testing facilities, and leads from numerous faculty have provided the best methods for identifying prospective industrial partners for their ERCs. The initial selection of prospective industrial members for the Center for Wireless Integrated MicroSystems (WIMS) was made on the basis of prior contacts by the University of Michigan (UM) Center for WIMS faculty, and from the faculty from two additional Michigan universities that are associated with the Center for WIMS. In contrast, when the current CD of the CBE was hired from the University of Calgary, he brought many industrial companies and faculty to the CBE.

The CDs from the Center for WIMS and from the CBE reported that it is extremely important to have upper management contacts within the companies because the annual membership fee usually requires an authorization from a financial decision-maker within the company. Center personnel need to provide specific benefits of the Center membership to the industrial champion, since he will be persuading upper management to renew the annual membership.

The Center faculty were reported by the industrial members, technology transfer personnel, the CD from the Center for WIMS, and both Industrial Liaison Officers (ILO) to have provided many of the industrial leads for the enlistment of companies to ERCs. Center faculty are usually, the first contacts by prospective industrial members after an industrial representative has read one of their publications or attended their research presentation at a conference.

Approximately fifteen patents have come out of CBE research, but the CD reported that many of the technologies have been freely given away. The CD from the Center for WIMS reported that many patents have been filed, and they have several provisional patents, but the Center is only in the fourth year of existence.

The CBE has spun-off two small companies from the Center, which has helped market the reputation of the Center. The Center for WIMS has had more companies spun-off from the previous research Center before it was funded from the NSF as an ERC. This is due to research being conducted at the Center for the past twenty years before the Center became an NSF ERC. The Center for WIMS has transferred a few technologies to industry, but the CD has claimed it is due to the youthful stage of the Center, and within a

few years there will be additional technologies transferred. In contrast, the CBE has transferred approximately ten technologies to industry, but many of them were freely given to the companies.

The CBE grants exclusive licenses to companies based on the amount of research money that companies spend on projects at the Center, and has a higher-tier membership for companies that are seeking research results and the Intellectual Property (IP) that may come out of the sponsored research. The CD at the CBE reported that he would rather receive revenue from industry for sponsored research and give the company the IP rights, than rely upon the patent system. In contrast, the Center for WIMS does not grant exclusive licenses because of the UM technology transfer policies. The companies have the option to negotiate for the IP, but they are rarely granted to the companies except for specific cases. The University of Michigan's (UM) reputation for performing quality research continuously draws numerous industrial representatives to their research facilities, and has greatly helped to market the Center. In contrast, Montana State University is the smallest institution to acquire a NSF ERC, but the Center's cutting-edge research, and international biofilm reputation has drawn numerous companies to their Center. Published articles in *Science* magazine have additionally, contributed to the marketing of the CBE.

Both Centers have established alliances with federal agencies, and with other universities. The Center for WIMS has Michigan State University and Michigan Technological University for alliances, and has added a few minority-serving universities in an attempt to increase diversity in their Center research efforts. The CBE has

established alliances with the University of Washington's NSF Engineered Biomaterials Center.

Industrial Liaison Officer Conclusions

The Industrial Liaison Officer (ILO) is a key figure in the building of Center-industry partnerships, and has numerous responsibilities in the marketing of Center research to industry. The ILO often is the person who invites the prospective industrial member to the Center after receiving the lead from the Center faculty, from a current industrial member, or from the CD. In other cases, the prospective member may have attended a technical conference, became informed and interested in the Center research, and contacted the ILO.

Center visits that do not involve a Technical Advisory Committee (TAC) or Industrial Advisory Board (IAB) meeting have been the most effective because visiting industrial personnel receive more attention from the Center faculty. Both Center ILOs reported that they had performed marketing research before making contact with specific industrial personnel to insure that the targeted prospective companies would benefit from Center research. Both ILOs attend many technical conferences to meet industrial personnel. The Center for WIMS has the assistance of the Corporate Relations personnel within the College of Engineering at the UM, to enlist UM alumni employed with industry who may have an interest in Center research.

There have only been a few failures when negotiating for exclusive licenses at the CBE, and the companies did not license, while the Center for WIMS and the CBE have

not had any companies withdraw their memberships for not receiving an exclusive license. The ILO from the Center for WIMS reported that the most successful methods for bringing in industrial sponsors has been establishing personal contacts and discussing company needs with the industrial representatives. The ILO from the CBE reported that the CD visiting company sites and making presentations to industrial personnel has been the most successful for their Center in bringing in industrial members.

The best methods for maintaining the current industrial members have been through direct personal contact between Center and industrial personnel by visiting industrial sites, and having industrial personnel visit the Center for WIMS. The Center for WIMS additionally has a Resident Engineer Program, an Industrial Speaker Program, and commercial lab equipment. Additionally, at the Center for WIMS, a faculty member has been assigned to each company, and is responsible for keeping in contact with the industrial representatives.

The ILO at the CBE reported that the most successful method for maintaining corporate membership has been to assist the industrial representatives in showing value of their membership to their upper management. Only a few companies have left the two ERCs, and the main reasons have been economics, mergers and acquisitions, or the champion was transferred. In addition, upper management has focused more on short-term results for solving company problems than for long-term research.

Conclusions for Technology Transfer Personnel

Technology transfer officers at MSU and the UM reported that the inventor has provided the best leads for licensing of inventions, and many of the leads are revealed within the disclosure process. Other methods that have been successful are asking the ILO for leads, and performing marketing and patent searches. Both officers send technology abstracts to the prospective companies after initial contact has been made.

The technology Licensing Officer (LO) at the UM reported that the IAB meetings at the Center, focused patent searches, and faculty attending conferences and making presentations have been the most successful methods for marketing university inventions to industry. The IAB and TAC meetings are crucial because they inform all of the industrial members of Center research at the same time. The LO at the UM reported that marketing multiple university inventions in a package has been successful. He additionally, reported that performing marketing research, contacting the correct industrial personnel, and making direct contact with the industrial personnel has been important in being successful.

The LO at MSU reported that the best methods for marketing university inventions have been to acquire leads from the inventor and from previous sponsors of Center research. The current LO at MSU, was previously employed as the ILO, and is very familiar with the CBE faculty, Center research, and the industrial members. He frequently asks the faculty for leads for prospective companies to license university inventions to their companies. He reported that he contacts the companies through email or telephone, provides the industrial representative with a technology description, and

continues to contact them and inquire about their interest in Center research.

At Montana State University (MSU), there are favorable inventor revenue returns for the faculty, and the indirect costs of the research are not taken out of the industrial funds. The Intellectual Property (IP) terms are more favorable for industry when they are tied to sponsored research at the Center. A higher-level Center membership is available for companies who desire IP ownership, but there are no members at this level. In contrast, the UM Licensing Officer (LO) reported that the university has not been flexible in their negotiations of IP terms, but the large companies continue to rely upon the Center research results.

The Center for WIMS allows the smaller Michigan companies to pay reduced membership fees while receiving the same benefits as the large companies. The CBE has a few small companies that are members through the assistance of the Small Business Industrial Associate (SBIA) Program. The Program allows small businesses that sponsor CBE research to participate in the Industrial Associate Program at a rate discounted commensurately with the research sponsorship. In addition, the Montana Biofilm Research Consortium (MBRC) allows small businesses to take advantage of the Center benefits and assists small businesses to adopt technological advances.

Both universities offer opportunities for companies to receive a first option to license the technology if an invention came out of Center research. This occurs when a company sponsors research at the university or the ERC. The UM does not grant exclusive licenses, while MSU does grant exclusivity for a Center technology if a company has sponsored the Center research which led to the invention. Both licensing

officers reported the necessity to be open to negotiations for the granting of exclusivity to the companies.

Conclusions from Industrial Personnel

According to the responses of the industrial survey, the initial contact between the Center and industrial personnel occurs by introductions of alumni, employees who were former students of Center faculty, Center faculty, ILO, and CD visiting company sites, industrial personnel meeting faculty at conferences, and Center web sites. The industrial survey revealed that the Center faculty mainly initiated the first contact between Center personnel and industrial personnel. Of the responses from all of the industrial personnel, only four industrial personnel claimed that the industrial personnel initiated the first contact.

In contrast, the CBE Center faculty claimed that the industrial personnel are the initiators of contact between the two parties. This difference in opinion may be explained from Center faculty not realizing that their publications, presentations at conferences, faculty web site, and visitation of company sites are the reasons that company personnel reported that the faculty were the initiators of contact between the two parties.

The responses of the industrial personnel indicated that the majority of the industrial companies joined the Center to gain knowledge, perform collaborative research with faculty, and to have access to Center faculty and students.

The industrial members provided methods for the Centers' to better market themselves to industry. One third of the companies reported that the Centers could

participate in conferences and trade shows to improve their marketing of the Center to industry. Some industrial members reported that existing members could market the Center, Center staff could contact more R&D personnel, use success stories, and market Center testing programs. Others reported that the Center could become a liaison for government regulators and industry, improve web site with members only section, contact quality organizations, advertise in scientific journals, and perform research that is closer to industrial application.

Industrial members reported a variety of recommendations for Centers that would keep them as members. The responses included more collaborative work with faculty, becoming a liaison with federal regulators and industry, advancing the value of the Center to upper management, stressing more applications training, and informing companies of the benefits of Center membership. Other members reported that performing small projects with students, providing current research that is relevant to company problems, keeping research costs reasonable, informing personnel of the expertise at the Center, making presentations about new technologies, providing educational programs, conducting technical meetings with subjects clearly expressed, providing recent publications and literature for the companies, performing small projects at no cost, performing joint publications with faculty, providing monthly newsletters for members, and having projects funded by federal agencies.

The majority of the industrial members from both Centers were satisfied with their investment in Center membership. A variety of answers were provided by the industrial members, which described the benefits of Center membership that were

particularly valued by their companies, but the majority of them stressed the importance of access to the Center faculty.

The benefits that were important to the industrial members were collaborative research, attitude of Center personnel, quality of Center faculty and students, the expertise of Center faculty, staff and students, high quality facilities, testing capabilities of the Center, conferences, publications, opportunities for Center research, and Center educational programs. Other valued benefits were knowledge gained from basic research, discussions with Center faculty about company problems, interactions with Center faculty and visiting scientists, and opportunities to fund small projects. In addition, discussions with Center faculty about research techniques and a company's research needs, faculty accessibility, the semi-annual TAC and IAB meetings, Center research presentations, the flexibility of research projects with Center faculty, the undergraduate visiting student program, and the testing lab facilities were important to the industrial members. Other industrial member responses from the Center for WIMS were Center research and equipment, interactions with students, the relevant Center technologies, and the interactions with Center faculty.

The industrial survey indicated that university technologies were discovered by industrial representatives attending conferences, reading publications, and canvassing. Other methods of finding university research have been through Society memberships, trade publications, web sites, and workshops. The industrial members reported that the occurrence of the methods employed for finding university research vary from daily to annually. The majority of the industrial members reported that attending conferences and

presentations, reading publications, attending workshops, and receiving referrals from research organizations and experts were methods for finding university technologies.

The majority of the industrial members reported that ownership issues, royalty issues, and publishing issues were the main inhibitors that may thwart Center-industry partnerships. Other issues that were reported by the industrial members were costs for research, less funding for research by the university, university bureaucracy, timeframes different than industry, and the inability to react to a spontaneous problem.

Conclusions from the Center Documents

The Center for WIMS

The NSF-Center for WIMS third year review documents reported a high degree of satisfaction for the strategic direction of the Center, and with the degree to which the individual objectives for membership were being served. Recruiting of students, Intellectual Property (IP) advantage, and technology awareness were reported as the main benefits of Center membership. In addition, the access to Center faculty for consultation, and the opportunity for networking within the IAB community were reported as benefits of Center membership. The members reported that their companies value quality students with strong systems training backgrounds. The Center for WIMS industrial member distribution has a higher percentage of small companies 48%, than the industrial member distribution for all ERCs, which is 24%. This may be due to the reduced ERC membership fees for Michigan-based small companies.

The Center for Biofilm Engineering

The primary marketing method for securing new industrial members as reported by the NSF site review documents has been invitations to prospective companies to attend the Technical Advisory Conference (TAC) meetings at the Center. The three primary sources of leads for prospective industrial members has come from the Center Director, marketing through the Center newsletter, and regularly soliciting referrals from current industrial members. The Center marketing for industrial members has been through the ILO contacting the prospective industrial member, providing Center information relating to the specific needs of the prospective member, and through invitation to the prospective member to attend the TAC meetings at the CBE.

The top five benefits of industrial membership were reported by the CBE industrial members in the NSF Third Year Site Visit documents. The prioritized benefits of Center membership were the (1) Opportunity to sponsor and recruit Center students; (2) Influence on Center research direction; (3) Technical Advisory Conference (TAC) meetings; (4) Integrating industrial relevancy into the Center research Program; and (5) Micro-scale to macro-scale level of research.

Research Questions Answered

This section will answer the two research questions using the results from the two case studies. Each question will be answered by presenting the similarities of practices that worked for the two Centers, and the practices that were different.

1. What are the best practices that resulted in building and maintaining ERC-industrial partnerships?

Similarities of the Two Centers

Consulting and the performing of research projects by Center faculty has provided the opportunity for bringing in new industrial members to an ERC. Center faculty from both Centers reported that the industrial personnel were the initiators of contact between the Center and industrial personnel. As a result of Center faculty being exposed to industry through presentations at conferences, publishing, faculty web sites, and previous consulting or research projects with companies, the majority of industrial personnel claimed the faculty as the initiators of the first contact between the parties. Both ILOs from the Centers reported that faculty are the largest sources of leads for industrial members.

Both Center faculties revealed that their main method of marketing the Center is through their attendance and presenting at conferences, Center web sites, and their publications. The majority of the Center faculty reported that answering phone messages, emails, visiting company sites, presenting at targeted conferences, inviting industrial personnel to technical meetings and workshops at the Center, publishing, and producing quality research are the best methods for building ERC-industry partnerships.

Center faculty from both ERCs reported that the elicitation of the company research needs or problems by Center personnel is key to maintaining industrial membership to the Center. In addition, Center faculty must provide specific information

to the industrial representative of the company, which enables them to convince their upper management, that the Center membership has been financially beneficial for the company.

The students from both Centers are used to market the Center when they present their research at conferences, and when they are employed by industry. Some of the students have returned to the Center as industrial representatives and as the Center champions within their companies.

Both CDs pass all the leads on to the Center ILO, who contacts the prospective industrial member, and invites them to attend a TAC or IAB meeting at the Center, or he has Center personnel visit the company site, and provide research presentations for the industrial personnel. Both CDs reported that it is extremely important to have upper management contacts within the companies because the membership fee usually, requires authorization from upper management.

Both of the Center marketing strategies involve Center faculty publishing, and making presentations at conferences. The best methods for maintaining the industrial members have been through direct personal contacts between Center and industrial personnel through visiting company sites, and having industrial representatives visit the Centers. In addition, Center personnel must provide value of the membership to the industrial representative in specific terms, to insure that the company's upper management renews the membership to the Center.

Both institutions provide opportunities for companies to receive a first option on the licensing of technologies for sponsored research, and the terms are more favorable to

industry when they are tied to sponsored research at the Center. Both Centers offer lower membership fees in order to accommodate smaller companies for membership to the Center. Initial contact between Center and industrial personnel occurs by introductions from alumni, employees of companies who were former Center students, referrals from other companies, publications, Center faculty, ILO, the CD visiting company sites, industrial personnel meeting faculty at conferences, and Center web sites.

The members provided recommendations for maintaining their companies as members of the Center. These included more collaborative work with faculty, becoming a liaison between federal regulators and industry, informing industrial upper management to the benefits of Center membership, stressing more application training for students, and informing companies of the benefits of Center membership. Other members reported that performing small research projects using students, providing research that is relevant to company problems, maintaining reasonable costs for research, informing industrial personnel of the expertise at the Center, making more presentations about new Center technologies, providing educational programs, conducting technical meetings with subjects clearly expressed, performing small research projects at no cost, performing joint publications with faculty, providing monthly newsletters, and providing recent publications and literature for the companies. With the variety of the responses from the members, it is apparent that each company has their company's specific needs, and specific benefits of the Center membership that are important to their companies.

University technologies are usually found by industrial representatives attending technical conferences, reading publications, referrals from research organizations and

experts, workshops, and canvassing. Other methods that were reported were through Society memberships, trade publications, web sites, and workshops. The occurrence of industrial search methods was extremely variable, and ranged from daily to annually to when needed.

The majority of the members reported that IP ownership, royalty, and publishing issues were the main inhibitors that may prevent Center-industry partnerships. Other issues were costs for research, reduced funding by universities, university bureaucracy, contracting timeframes between the cultures, and the inability to react to spontaneous problems were inhibitors to Center-industry partnerships. Members expressed the importance for companies to participate in jointly sponsored research. Research meetings with Center faculty were very important for the majority of the industrial members, and Center workshops, in-house training, and advising and consulting from Center faculty were additional important benefits of the Center membership.

Differences Between the Two Centers

The Center faculty were reported by the industrial members, the LOs, the CD from the Center for WIMS, and both ILOs to have provided the most leads for the enlistment of companies to ERCs. Although the CBE faculty acquires the most leads, the ILO reported that the CD acquires the best leads. In contrast, the CBE faculty claimed that the industrial personnel were the initiators of the first contact between Center and industrial personnel.

The Center for WIMS has an Industrial Speaker Series, a Masters of Engineering Program for industrial employees returning to college, and a Resident Engineer Program for industrial employees exercising a sabbatical from their companies to train at an ERC. These programs assist in the marketing of the Center for WIMS to industry, and in building research partnerships.

The College of Engineering Corporate Relations staff informs the Center for WIMS Industrial Liaison Officer (ILO) of all UM alumni that are employed with industrial companies. The ILO contacts the alumni and initiates a relationship in the anticipation of bringing in an industrial member to the Center. This practice assists in marketing of the Center through the usage of alumni contacts.

There was variation in the opinions among the CBE Center faculty of how industry became aware of them. These consisted of the Internet, Center web site, publications, conferences, company visits, TAC or IAB meetings, and referrals from other companies. In contrast, the Center for WIMS has been in existence for two decades prior to becoming a NSF-ERC, and the industrial personnel were already familiar with many of the Center faculty.

The CD for the Center for WIMS generates approximately 50% of the industrial leads, while the Center faculty generate the other 50%. The CD for the CBE generates the best leads, but the faculty generates the most leads. The CD for the CBE reported that publishing, having quality testing facilities, and leads from numerous faculty have provided the best methods for identifying prospective members for the Centers.

The CBE has had more patents issued than the Center for WIMS, but the CBE technologies are usually, freely given away to companies and federal agencies. The Center for WIMS is only in the fourth year of funding with the NSF. The Center has had very few issued patents, but numerous provisional patents.

The UM College of Engineering Corporate Relations staff passes industrial leads on to the ILO at the Center for WIMS. The leads consist of industry employed alumni, which the ILO contacts to initiate the Center-industry relationship, and to determine the degree of company interest in Center research. The ILO from the Center for WIMS reported that the Center faculty and Corporate Relations personnel provide the best leads. The exchange of leads is informal, and Center personnel pass their leads on to the ILO of each Center.

The Center for WIMS ILO reported that the best methods for bringing in industrial members has been establishing personal contacts and discussing company needs with industrial personnel. The CBE ILO claimed that having the CD visit company sites and provide presentations to industrial personnel has been the most successful method for bringing in industrial members.

The LO from the UM reported that the marketing of multiple inventions in a package have been successful. The differences between the two LOs at the Centers are that the LO from the CBE contacts previous sponsors of university research, and the LO from the Center for WIMS conducts related patent searches to find prospective industrial personnel seeking university inventions to license.

MSU offers favorable inventor returns, and the IP ownership is tied to sponsored research at the Center. MSU allows full ownership with a higher level Center membership for $80,000 per year. MSU technology transfer appears to be more open to negotiations with industry for the offering of exclusive licenses. The UM has technology transfer policies that rarely allow an exclusive license for the company.

The Industrial Advisory Board (IAB) and Technical Advisory Conference (TAC) meetings are conducting for the same purpose at each Center, but the formats are different. Their purpose is to inform industrial personnel of Center research, and allow Center and industrial personnel, as well as students to interact and network at the conferences. The TAC meetings provide research presentations by faculty and students, poster sessions, workshops, and numerous meetings involving industrial members and Center staff. In contrast, the IAB meetings involve short presentations of research and the student poster sessions. The conference is formatted to maximize networking for all personnel, and keep attendees from prolonged sitting and moving throughout the conference.

The NSF site visit documents for the Center for WIMS third year review reported that recruitment of students, Intellectual Property (IP) advantage, and technology awareness were the main benefits of Center membership for the industrial members. In addition, the access to Center faculty for consulting, and for the opportunity for networking with the other members at the IAB meetings were benefits of Center membership for the members.

The NSF site visit documents revealed that the main CBE marketing methods for

securing new industrial members has been through invitations to prospective companies to attend the TAC meetings. The primary sources of leads at the CBE have come from the CD, the Center newsletter, and regularly soliciting referrals from current industrial members. The CBE marketing of the Center has been mainly through the ILO contacting the prospective companies, providing information for the specific needs of the prospective member, and through invitation to the TAC meetings at the Center.

The Center for WIMS has a higher percentage of smaller companies than the CBE. This probably is a result of the State of Michigan's strategy to promote small business activity with the three Michigan universities, with the assistance of the UM and Center for WIMS providing a reduced membership fee to the Center for the Michigan companies.

The top five benefits of CBE membership were reported to the NSF site review committee from the industrial members. The prioritized benefits were the opportunity to sponsor and recruit CBE students, influence on Center research direction, TAC meetings, integration of industrial relevancy into the Center Research Program, and research ranging from micro-macro in scale.

2. What practices did not assist in building and maintaining ERC-industry partnerships?

Similarities of the Two Centers

Mass mailings, cold calls, sending literature without follow-up, and any methods that do not include personal interactions with industrial personnel were reported by both Centers as unsuccessful methods of bringing in industrial members.

Dissimilarities of the Two Centers

This study did not identify any differences of the two Centers for unsuccessful methods for building and maintaining Center-industry partnerships.

Recommendations

While this comparative case study data cannot be generalized to other institutions, other ERCs can make comparisons to their own institutions and evaluate which aspects of these findings might apply to their environments. The findings and recommendations that these individuals might evaluate as beneficial include the following recommendations.

Recommendations for Engineering Research Centers

1. Center faculty should assess the duties of their Center Director. If the CD travels to conferences, makes numerous presentations, publishes extensively, and is able to generate numerous industrial leads, then the faculty can focus more on maintaining existing memberships with the industrial members.
2. Faculty and Directors should be creative in their methods to create industrial memberships. Some of these methods might include:
    A. Industrial Speaker Series, which invites industrial personnel to the Center for speaking engagements, followed by meetings with Center faculty, and an introduction to the Center facilities.
    B. Work with the College Deans and Graduate Schools to establish a Master's Program in Engineering within the Center that aligns more

closely with industrial applications. The program can additionally, be tailored for industrial personnel returning to school for a Masters in Engineering Program.

C. Enlist the assistance of the institution's Alumni Office to inform Center personnel of alumni working with industry, and for alumni staff to act as a liaison between the alumni and Center personnel.

D. Change the format of the TAC or IAB meetings to include more opportunity for industrial members to network with other members and with the students. Shorter presentations and poster sessions would allow personnel to be networking with less sitting for lengthy presentations.

3. Center personnel could invite the most promising prospective members to their ERC when there is no TAC or IAB meeting to insure that the prospective personnel receives faculty attention. The prospective member would leave the Center with information to inform the company's upper management about the Center, which may result in the company joining the Center.
4. The Center ILOs could exchange industrial leads with the university technology transfer staff.
5. The Center could have communication workshops for the faculty to improve their communication skills with industrial personnel.
6. Center personnel could cultivate multiple champions within all industrial companies of the Center, to insure against losing key industrial contacts to retirement or through company transfer.

Recommendations for the University

1. The university and the ERC may use industry's strong student interest and their employment record as marketing tools in drawing more students to their universities, and to their Engineering Schools and ERCs.
2. Universities could possibly harm their reputations by sending out mass mailings of unproven technologies to industrial companies, who may interpret a mass mailing or cold call as a desperate attempt to unload an unproven technology that other companies have rejected.
3. Universities that have an ERC could encourage and assist the Center faculty, CD, ILO, and graduate students financially, by sending key personnel to targeted conferences to meet the right industrial personnel. Though MSU is a much smaller university than the UM, the institution can market their internationally known Center for Biofilm Engineering (CBE).
4. The MSU Technology Transfer Office could create and implement IP policies to build their institution's reputation of transferring quality technologies with the assistance of knowledgeable technology transfer staff that practices negotiation of IP with sponsored research partners. This could reduce the free exchange of IP to industrial partners, and possibly bring in more revenue to the CBE, and to the university.
5. The university could offer communication workshops for university research personnel to provide faculty an opportunity to improve their communications skills with industry.

Recommendations for Industry

1. Companies need to be patient and maintain their memberships at an ERC over several years. They must realize that more opportunities and benefits will be available for their companies with a continuing membership, than attempting to solve company problems over the short term. Companies need to seek an active role in the ERC, and inform Center faculty of the specific problems that their company is attempting to solve at an early stage of the Center-company relationship.
2. Companies need to recognize that the two cultures have different missions, objectives, and time constraints, but with a team effort, the relationship could quickly grow and last longer, and personnel from both cultures will learn more about their partners needs and expectations.
3. Industrial personnel need to attend conferences where targeted Center faculty will be presenting their research. The faculty could be contacted before attending the conference to arrange a meeting between the two parties after the presentation.
4. Companies could have their personnel publish articles that reveal university technology searching methods. This could assist university technology transfer staff and NSF ERCs to create better marketing methods to coordinate with the specific technological needs of industry.

Recommendations for Future Research

An area of research that had minimal coverage in the researcher's literature review that would be beneficial to universities and to industrial companies was the methods that companies use to find and license university technologies. The researcher attempted to find some of the methods in the case studies, but it was not the major intent of the study. Industrial members reported that they attend conferences, read publications, and canvas universities for the current technologies, but the specific techniques within the industrial companies were not revealed, and the occurrence of the methods employed in searching for university technologies varied from daily to annually to when needed.

Research of the methods and techniques used by leading industrial companies that lease university inventions, may be beneficial in providing universities and ERCs with better marketing methods to entice the technology-searching companies to lease their inventions.

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APPENDICES

APPENDIX A

ERC-CORPORATE SURVEY

ERC-Corporate Survey

1. How was the initial contact between the Center and your company established?

2. Who initiated the first contact between Center and industrial personnel?

3. Why did your company join the Center as an industrial member?

4. How can the Center personnel improve their marketing to prospective industrial members?

5. How can the Center improve and maintain your industrial membership?

6. Are you satisfied with your investment in membership to the ERC?

7. What benefits of Center membership are particularly valued by your company?

8. What aspects, if any, have not met your company's expectations?

9. What methods are used within your company to find university research?

10. How often are the methods employed in seeking out university research?

11. Which methods in seeking university research provided your company with the best results?

12. What factors within the university may inhibit the research partnership of an ERC and your company?

13. On a scale of 1-5 with 1 being extremely important and 5 being low importance, how important is:

13A. The ability to participate in additional jointly sponsored research projects, 1 2 3 4 5

13B. The ability to sponsor proprietary research, 1 2 3 4 5

13C. Direct access to new graduates, 1 2 3 4 5

13D. Research meetings, 1 2 3 4 5

13E. Workshops, 1 2 3 4 5

13F. In-house training options, 1 2 3 4 5

13G. Other (please explain), 1 2 3 4 5

APPENDIX B

QUESTIONS FOR THE INDUSTRIAL LIAISON OFFICERS

Questions for the Industrial Liaison Officers

1. What kind of system do you use for tracking Center-industry interactions?
2. How do you determine which companies to approach for industrial membership?
3. Who provides you with the greatest amount of leads?
4. Do you ask the Center Director, Center faculty, inventor, and university technology transfer personnel for leads?
5. How many patents have been granted by your Center?
6. How many technologies have been transferred to industry?
7. Does your Center usually grant exclusive licenses to industrial members who provide a large amount of research support?
8. What is the most successful method that brings in corporate sponsors?
9. What is the Center's strategic marketing plan for recruiting industrial members?
10. What is the least effective way to enlist industrial members to your Center?
11. What are the best methods that help maintain the current industrial members?
12. What methods have caused industrial members to not renew their memberships?

APPENDIX C

QUESTIONS FOR THE CENTER DIRECTORS

Questions for the Center Directors

1. How do you identify potential new Center partners from industry and establish contact with them?

2. Does the Industrial Liaison Officer ask the CD for industrial leads?

3. How many patents are a result of the Center research?

4. Has your Center spun-off companies which have become industrial members of your Center?

5. How many technologies has the Center transferred to industry?

6. Does the Center usually grant exclusive licenses based on the amount of expenditures for research that a company has provided at your Center?

7. How do you articulate your vision of the ERC to industry?

8. How do you articulate your vision of the ERC to university administrators?

9. Have you established research alliances with other universities?

10. Have you established alliances with other federal agencies?

11. What are your best marketing methods for building ERC-industry partnerships?

12. What methods have not improved Center-industry partnerships?

13. How has the Center marketing interactions with industry evolved over the years?

APPENDIX D

QUESTIONS FOR CENTER FACULTY

Questions for Center Faculty

1. Have you done previous consulting for any of the companies that are current or past industrial members of your Center?

2. Who initiated the first contact in the relationship with the companies and yourself?

3. Does the industrial liaison officer at your Center ask you for industrial leads for prospective new members?

4. How do you as Center faculty, market the Center to industry?

5. What are the best methods that build ERC-industry partnerships?

6. What works the least in building Center partnerships with industry?

7. Do you feel your students have contributed to industrial members joining or maintaining their membership at the Center?

APPENDIX E

QUESTIONS FOR
UNIVERSITY TECHNOLOGY TRANSFER PERSONNEL

Questions for University Technology Transfer Personnel

1. How many personnel in your technology transfer office are responsible for the ERC technology transfer processes?

2. Do you ask ERC faculty, the Industrial Liaison Officer (ILO), Center Director (CD), or inventors for industrial leads?

3. What university policies do you believe make it easier for industrial sponsors to join the ERC at your campus?

4. What are your best methods for the marketing of Center inventions to industry?

5. Do you usually grant exclusive licenses to companies who have sponsored research at the Center?

6. Does granting an exclusive license improve your licensing results for ERC inventions?

7. What are the methods that the university uses to ripen technologies to make them more attractive to industry?

APPENDIX F

INTERVIEW REQUEST LETTER

Interview Request Letter

Frank Boschi
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Dr. Costerton
Center Director
Center for Biofilm Engineering
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June 10, 2003

RE: Interview Request for Doctoral Candidate

Dr. Costerton,

Since you were not available for an interview the week of July 9, 2003, I am asking you to complete a few questions concerning ERC Directors, and their opinions for best practices for building ERC-industrial partnerships. After completion of the questions, please return to the researcher via the enclosed stamped envelope.

I appreciate your time in filling out the interview questions, and I assure you of the confidentiality of this information will only be used for the completion of my doctoral thesis of best practices for Building and maintaining ERC-industry research partnerships. I will send you a copy of the completed thesis upon my successful defense of the thesis.

Again, I thank you for your opinions and for taking the time to answer these questions.

Sincerely,

Frank Boschi
Ed.D Candidate