NON-TRADITIONAL TECHNOLOGY TRANSFER

By

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DEDICATION

This dissertation is dedicated to Charles E. Mallon who passed away during its development. He did not have a college education but understood its value and made certain that his children did as well.

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ABSTRACT

The concept of industry transferring work to academia is developed and studied using multiple cases at three different university research sites. Industry sometimes partners with academia specifically to have academia perform work with certain equipments or obtain knowledge for the purpose of process, product or knowledge development. The term “non-traditional” technology transfer is introduced to describe this activity. Case studies using research faculty and their students as well as industry partners were conducted at two Engineering Research Centers and an engineering department of a relatively smaller institution that has developed an engineering clinic approach to research. The literature drawn upon includes: historical perspectives of the academia-industry technology transfer arena (including the Bayh-Dole Act of 1980), trends, the relationship between academic capitalism and technology transfer and the role played by technology transfer in environmental research. Findings of this study indicate that industry has, in some cases, chosen to have their collaborative research team partners accomplish work for them. Access to resultant data is difficult to obtain and has implications for the concept of academic freedom. Advantages of the technology transfer process include the generation of value for each of the project partners, education of graduate and undergraduate students and benefits to the public good in terms of the environment; disadvantages are identified but considered uncertain. Technology transfer, including the non-traditional type defined herein, can be used as a tool to overcome the reality of

today’s austere university budget environment; the Bayh-Dole Act has served as an enabler of that approach.

CHAPTER ONE : INTRODUCTION

> The effort to improve the conditions of man, however, is not a task for the few. It is the task of all nations--acting alone, acting in groups, acting in the United Nations, for plague and pestilence, and plunder and pollution, the hazards of nature, and the hunger of children are the foes of every nation. The earth, the sea, and the air are the concern of every nation. And science, technology, and education can be the ally of every nation.
>
> John F. Kennedy
> September 20, 1963

Forty-five years after President Kennedy's address to the General Assembly of the United Nations academic and industrial forces are acting collaboratively to bring technological solutions to bear on a wide spectrum of environmental problems. In the United States these collaborative scientific research efforts are frequently funded, directly or indirectly, by the federal government in a manner unlike any other nation. Such teaming relationships between academia and industry sponsored by government may result in benefits not only for the participants but also the nation's citizens due to favorable environmental impacts.

The process of federal agencies using scientific research to develop commercially attractive technologies and the requisite industrial strategies to exploit them in the marketplace is commonly known as technology transfer. In the years before 1980, this traditional form of technology transfer was not working in an optimal or even desirable manner. A considerable amount of technology paid for by the United States government for use by its taxpayers never reached the marketplace simply because developers were not motivated to take it there. Federal tax dollars granted to engineering and science schools at the nation's colleges and universities were used to develop products and processes. Arcane government regulations kept those technologies from benefiting the common consumer.

By 1980 the United States government (USG) held title to tens of thousands of patents (legal document conferring title) developed by universities using federal research monies. Only 5% of those patents were licensed to industry for commercial development. Additionally, the number of patents issued by the US Patent and Trademark Office to universities in 1980 was only 250. Clearly, technology development paid for by tax dollars was not making it to the marketplace for use by the nation's consumers. In 1980 Senators Bayh and Dole enacted legislation to address this situation; the resultant Bayh-Dole Act proved a watershed event. That law served as legislative direction for a uniform, simplified and profit driven approach to licensing and patenting. The law's clear intent was the optimization of the process of knowledge and technology transfer from academia to industry; it achieved its intended purpose. Academic technology developers were motivated to intensify their interaction with the marketplace due to the enhanced potential of profits that could benefit themselves, their parent organizations and ongoing research efforts.

As will be discussed below, over the twenty-eight years since the passage of the Bayh-Dole Act in 1980 a significant body of scholarly work has been published concerning the transfer of technology and knowledge products from academia to industry and the exponential growth of that activity that the law has spawned.

During the same timeframe that led to and produced the large growth of technology/knowledge transfer activities another concept also took firm root and experienced considerable growth: the global awareness of the frailty of our planet's environment. The decade of the 1970s saw the creation in the United States (US) of the Environmental Protection Agency (EPA) and the early 1990s saw that same organization spawn and spread the principles of Green Chemistry and Engineering. That awareness reached a new height recently when a United Nations organization, the Intergovernmental Panel on Climate Change, founded in 1988, was awarded (jointly with former US Vice President Al Gore) the 2007 Nobel Peace Prize. That honor was awarded for their ability to disseminate knowledge about climate change and measures needed to counteract such change. Those measures include, as President Kennedy alluded to some 45 years ago, new ideas and technologies to address the global problem that, to a very large extent, only science can enable. This study will focus on the fruits of some of those new ideas and technologies: scientific efforts executed in an academic setting and made manifest to the public through collaborative efforts with industry within the broad context of technology transfer.

The National Science Foundation (NSF) annually awards considerable amounts of money to universities for research activities in the categories of general science, engineering and environmental science. Similar awards are made by other US mission agencies (e.g., EPA and the Department of Energy (DoE)). The above noted ascendant awareness of environmental matters on both the global and national planes, coupled with the traditional US federal funding levels of environmental research across a broad spectrum of institutions, presents a fertile ground for research into technology transfer activities. This exploratory study was intended to draw on that large body of research effort and its relationship to technology transfer by using multiple environmental research projects at different universities as case studies.

Some of the above government-funded activities are conducted on applied research projects that are performed collaboratively with industry partners. Enabled by Bayh-Dole, the fruits of those projects sometimes flow to industry while academia is rewarded with new income streams. Noteworthy is the fact that some subset of those activities, and other projects performed without current federal funding, utilize equipment or knowledge developed by funding independent of current federal financing. Examples include: research lab equipment funded by previous federal projects or an independent university benefactor as well as the human capital associated with faculty knowledge, skill and experience developed prior to current activity. Thus, industry sometimes partners with academia specifically to have academia perform work with certain equipments or obtain knowledge for the purpose of process, product or knowledge development that they would otherwise have to pay for were they to perform the work themselves. In effect, industry transfers work to academia. This researcher will henceforth call this category of effort “non-traditional” technology transfer. As noted above, “traditional” technology transfer, frequently funded by the US federal government, occurs when scientific research is performed in academia to develop commercially attractive technologies while industry develops the requisite industrial strategies to exploit them in the marketplace. Although the fruits of non-traditional technology transfer can, and often do, make it to the marketplace, that resultant is not necessarily the motivation for performing the effort. Rather, the effort may be performed by academia at the behest of or in collaboration with industry for entirely different reasons such as income savings/generation, education, or even to serve as a recruiting tool for potential future employees. Each of those motivations is explored in this study. As noted above, considerable academic inquiry, before and since Bayh-Dole, has been done on the topic of traditional technology transfer. Little scholarly work has been performed to clarify the subtle or non-traditional form of technology/knowledge transfer creating an apparent literature gap in the understanding of and accounting for these activities and the motivation for them. To those ends the following research questions shall be investigated:

- What is the nature of the collaboration between the members of the university-industry partnerships conducting environmental research?
- What is the motivation for each member's involvement in the university-industry partnerships conducting environmental research?
- To what extent is the collaborative environmental research project being conducted to improve the overall ecoefficiency of the firm?

Following this chapter's introduction, Chapter Two will set the background, context, and brief historical perspective for the above research questions by providing the literature review for the chosen subject matter. Chapter Three will then provide the detailed research approach for this mixed methods case study. Chapter Four presents, in largely narrative form, results of analysis and interpretation of the gathered data. Note that in addition to addressing the above research questions, Chapter Four also presents unexpected findings concerning access to research teams and the impact of research team involvement on student recruiting. The study then concludes with Chapter Five, which presents implications of this inquiry as well as recommendations for potential future research questions.

Purpose

The explicit purpose of this mixed method multi-case study is to explore the relationship between academia and industry during the non-traditional transfer of technology or knowledge products within research teams formed between a firm and a local university. The central academic focus of this inquiry is college and university engineering schools due in part to the large share of the total US Research and Development (R&D) expenditures that they are granted each year from NSF and other US government mission agencies. Knowledge gained concerning this non-traditional form of technology transfer activities may be advantageously utilized by different industrial firms and/or engineering schools at different universities. Specifically, the knowledge, which served to focus research efforts on certain types of environmental problems, may assist another organization as it seeks to secure scarce funding from the various government mission agencies. This is particularly pertinent to an NSF sponsored Engineering Research Center, an organization comprised of several universities and firms all of which conduct business differently. The shared knowledge from this investigation may prove useful to some of those participants. Similarly, other organizational relationships, also the subject of this study, may provide quite different insight as a result of this inquiry. As an example, in the case of the relationship between the Chemical Engineering Department of Eastnorthern University and Corporation Mike (CM), Eastnorthern uses faculty led teams of undergraduates to conduct applied research projects to solve real world engineering problems at CM. Eastnorthern students learn and obtain course credit while CM gains the transferable products of their work. Additionally, those student teammates serve as an example for other potential benefits: while participating in team activities they also gain insight regarding the desirability of CM as a future employer while CM simultaneously benefits by obtaining an understanding of each participants' overall skill set and their concomitant potential as a company employee. Knowledge of a technology transfer program that serves educational goals while simultaneously acting as a recruiting tool may prove useful to other engineering colleges seeking a similar relationship with industry.

There was a secondary but clear motivator for the selection of the particular cases chosen for this investigation. Although some of these non-traditional technology transfer research efforts were performed to enhance a company's competitive advantage in the marketplace and academia may have garnered added income, the environment, either purposefully or serendipitously, may also have benefited. Indeed, the betterment of the environment may have been a profitable project's primary goal; thus, within the chosen theoretical framework of academic capitalism, the selected category of research projects was considered particularly interesting.

Significance

This exploratory inquiry is significant due to its intention to expand the scholarly knowledge base concerning a subtle form of today's industry/academia technology transfer processes. The methodology utilized to obtain and analyze the requisite data to expand that knowledge base is presented in Chapter Three, an overview of the research design and its methodology, including the above research questions. Chapter Three also describes the unit of analysis: the NSF sponsored Engineering Research Centers at Southwestern University and Southeastern University as well as the Chemical Engineering Department of Eastnorthern University. Details and limitations of the collaborative environmental research projects from each of those institutions and their industrial partners that served as this inquiry's case studies are briefly described. The design overview also provides detail concerning the mixed methods (quantitative and qualitative) of the research approach used to gather and analyze the data. Lastly, inquiry limitations and advantages as well as a statement of researcher positionality are presented.

Preceding the discussion of the research design is the literature review of technology transfer provided in Chapter Two. That review includes historical perspectives of the academia-industry technology transfer arena, developed and emerging trends, the relationship between academic capitalism and technology transfer, the role played by technology transfer in environmental research and sustainable development and the potential impact of student collaborative team participation on recruitment (academe and industry) and engineering education. The literature review provides background and an overview of academic capitalism, the theory that serves as the theoretical framework for this inquiry. Noteworthy is the fact that academic capitalism (AC) has been developed since the enactment of Bayh-Dole and that the concept details the growing maketization or market like behaviors of academia for the purpose of income stream generation. The originators of that theory consider traditional technology transfer as a prime example of academic capitalism: an academic activity performed to serve industrial development for the purpose of earning income (e.g., license/royalty fees) for the university and themselves.

Following Chapter Three's description of the general investigative approach, Chapter Four then provides the detailed results of the data analysis, which was accomplished using the established research methodology. A narrative approach to Chapter Four has been utilized. The results of the data analysis are not presented as stand alone chunks of raw data; rather, salient findings are presented, interpreted and connected in a logical and meaningful manner with supporting data provided as appropriate. Included in Chapter Four is a review of the gap in the current literature concerning the non-traditional form of technology transfer as described above. This apparent gap is explained in the context that in general, when working together, both academic and industrial participants in both the traditional and non-traditional technology/knowledge transfer processes are quite reluctant to provide access to their work and/or release data and discuss their efforts. That reluctance to share data was and is likely motivated by multiple reasons including the potential for competition sensitivity of products and processes. Motivation for that reluctance will be explored deeper in Chapters Four.

Noteworthy also is the fact that, regardless of precise motivation, this general unwillingness to provide access and release data has made this research effort an investigative challenge, yielding a limited data set. However, that data set, although limited and difficult to obtain, has produced results rich in detail and, in some instances, revelatory. In addition to the discussion regarding data access, Chapter Four also provides data analysis and discussion regarding motivations for industry and academic participation on collaborative research teams as well as the relationship of those partnerships to the theory of academic capitalism. Interpretation of data is also presented concerning the environmental impact of the subject case studies. Finally, and quite surprisingly to this investigator, Chapter Four addresses the revelatory finding with supportive evidence regarding the relationship of the subject case studies to the student recruiting practices of both academic and industrial participants including possible motivations and impacts on engineering education.

Chapter Five will outline the implications of this inquiry and potential future research questions. Specifically, the importance of the information provided in this study will be addressed including its potential impact on the concept of “soft skills” such as student performance on teams in engineering education. The importance of collaborative team participation to the practice of student recruiting by both industry and academia is posed as a future research question; a deeper exploratory look at undergraduate participation on industry/academic collaborative research teams is considered.

CHAPTER TWO: LITERATURE REVIEW

This chapter will present four sections of research relevant to the study: historical perspectives of the academia-industry technology transfer arena, developed and emerging trends, the relationship between academic capitalism and technology transfer and the role played by technology transfer in environmental research and sustainable development.

Historical Perspectives of Technology Transfer

After World War II the forerunner to the National Science Foundation (NSF) was founded and was key to the implementation of the Vannevar Bush model that established a uniform approach toward basic scientific research: individual projects at the nation's various research universities were funded at the discretion of individual US government (USG) mission agencies. Noteworthy is the fact that much of the USG sponsored research was of an applied nature due to support from agencies such as the Department of Defense (DOD) (Mowery, et al, 2001). Over time research budgets exploded while the share of industry funding for those efforts declined. Additionally, wide variation developed amongst the individual funding agencies regarding patent policies (Henderson and Smith, 2002). DOD first permitted a limited set of institutions to retain title to any patents resulting from its funded research. Other USG agencies followed suit using their own criteria and processes. This non-standardized approach resulted in confusion for all participants (academia, industry and government).

In 1980 the United States Government enacted into law the Patent and Trademark Law Amendments Act, commonly known as The Bayh-Dole Act. The above noted confusion provided, in part, the necessary impetus for the law's passage. As stated above, before Bayh-Dole government held title to approximately 28,000 patents, only 5% of which were licensed to industry for commercial development and the number of patents issued by the US Patent and Trademark Office (USPTO) to universities in 1980 was 250. The Bayh-Dole Act served as legislative direction for a uniform, simplified and profit driven approach to licensing and patenting with the clear intent of better optimizing the process of knowledge and technology transfer from academia to industry. Process standardization was not the only motivation for Bayh-Dole. Rather, concerns over US economic competitiveness also motivated the law's passage; it was intended to serve as a principal enabler of the commercialization of the products of academic research funded by federal dollars (Mowery & Sampat, 2005). Further, the law's passage resulted in the US becoming the only country whose universities could hold title to intellectual property developed by faculty from efforts financed by federal funds (Slaughter & Leslie, 1997). Today, Bayh-Dole is considered a success if not a watershed event. From a historical perspective, technology transfer by academics did not begin in 1980; rather, the early twentieth and late nineteenth centuries, witnessed a great deal of applied research by academia, often partnered with industry and independent of the US government (USG). The agrarian nature of US economic history accounts for much publicly funded university research in agriculture. Collaborative efforts were not uncommon between university faculty and industry: in 1912 the Research Corporation was first formed by a UC Berkeley professor to commercialize his invention and the academic discipline of chemical engineering was developed by the petroleum/chemical industries in conjunction with the faculty of MIT and the University of Illinois (Mowery & Sampat, 2001).

Trends

Some fundamental statistics demonstrate that much has happened in the academia-industry technology transfer arena since the passage of the Bayh-Dole Act. In 1996 the Association of University Technology Managers (AUTM) survey of nearly 200 of the largest research institutions reported close to $20.56 billion in total research expenditures by US universities, hospitals and research institutes; 66% of which was funded by the federal government, 9% by industry (See Table 2.1) and the remainder by state and local governments, foundations, individuals and the institution itself (AUTM, 2007). A Jensen and Thursby survey of Technology Transfer Offices (TTO) personnel found that the significantly greater university licensing activity falls in the following dominant categories: medicine/nursing (44%), engineering (25%), science (19%) and agriculture (5%) (Jensen & Thursby, 2001).

NSF annually conducts a wider survey than AUTM, comprised of over 660 institutions each with at least $150,000 in R&D expenditures: in 1996 the total R&D expenditures were $23.05 billion, 60% of which was attributed to the federal government and 7% to industry (NSF, 2007). Additionally, in 1996 universities and research institutions filed for approximately 2,500 patents. By 2006 the AUTM statistics concerning total research expenditures and patents filed had climbed dramatically: total R&D expenditures more than doubled, climbing to $45.40 billion and patents filed increased nearly five-fold to 11,622. At the same time, funding sources stayed close to flat: 68% from the federal government and a slight decrease to 7% from industry (AUTM, 2007). Somewhat differently, the NSF survey reports $47.76 billion total R&D

expenditures in 2006 with the federal government contribution increasing to 63% and industry's share decreasing to 5% ($2.39 billion). Also noted in the NSF survey is that in 2006, of the total R&D expenditure, 5.4% ($2.6 billion) was spent on environmental sciences and approximately 14.8% ($7.08 billion) on engineering (See Table 2.1). Clearly, commerce in the technology transfer area has intensified; universities now establish Technology Transfer Offices, staffed with legal, technical and program experts, to manage this new potential income stream.

Another mechanism utilized to facilitate this key economic process of technology transfer is formation of a research joint venture (RJV) between a firm and a university. Panagopouloos (2003) showed that formation of an RJV partnership is most likely to occur when the subject is new technology. This is likely due to lower opportunity cost; i.e., a firm (university) is more likely to partner on a new technology since the profits it sacrifices by halting the research on its own are minimal (Panagopouloos, 2003). Yet another reason for these partnerships is the beneficial spillover (i.e., derived patents) effect of lowering the degree of intellectual property protection. Santoro and Bierly have observed

Table 2.1: R&D Funding

Data Source	**NSF**		**AUTM**	
Year	**1996**	**2006**	**1996**	**2006**
Total US R&D Expenditure ($B)	20.56	45.4	23.05	47.76
By Source				
Fed Gov't	13.84 (60%)	30.03 (63%)	13.57 (66%)	30.87 (68%)
Industry	1.61 (7%)	2.43 (5%)	1.85 (9%)	3.18 (7%)
By Discipline				
Environ Sciences	1.48 (6.4%)	2.6 (5.4%)	NA	NA
Engineering	3.67 (16%)	7.08 (14.8%)	NA	NA

that as the economy becomes increasingly global in scope firms will reduce their basic core competencies to sustain their competitive advantage; instead they will depend on the network of supporting partnerships formed with universities/institutions for the purpose of knowledge and technology transfer (Santoro & Bierly, 2006). Santoro and Chakrabarti (2001) reported that firms are motivated to form relationships with universities to gain access to high technology and highly trained personnel as well as excellent facilities and to improve prestige. In turn, universities maintain these same relationships to obtain industrial funding which has the distinct advantage of less administrative requirements than funds from the government (Santoro & Chakrabarti, 2001). And, Santoro and Chakrabarti later observed that large firms are more likely to seek knowledge transfer with universities to strengthen their non-core competencies; in contrast, small firms seek those same relationships to strengthen their core technological competencies (Santoro & Chakrabarti, 2002).

Today's considerably greater volumes of patenting and licensing activity and their spread across a wider breadth of the nation's universities have precipitated numerous industry and university partnerships and joint ventures to accommodate the ever increasing traffic. It is apparent that the intent of Senators Bayh and Dole to accelerate economic development by the more focused usage of federally funded university research projects has been fulfilled. The nation's citizens have been served with a wide array of highly technical products and the country has sustained a significant level of global competitiveness.

Academic Capitalism

Slaughter, Leslie and Rhoades would likely argue that academe has paid a price for the type and volume of economic activity: the rise of academic capitalism with its concentration of the academy on more and greater streams of income and the concomitant diminishment of service of the public good by research performed by the professoriate.

The late 1990's witnessed the development of the concept of academic capitalism (terminology first presented by Hackett in 1990). Slaughter and Leslie, using both qualitative and quantitative data from public research universities in four English speaking countries, defined academic capitalism (AC) as "… institutional and professorial market or marketlike behaviors to secure external moneys …" (Slaughter & Leslie, 1997, p. 8). These behaviors, viewed as an example of resource dependency theory, are considered by those authors to be a direct response to the globalization of the political economy that occurred during the closing years of the twentieth century and the concomitant decrease in funding of higher education systems by governments. More state funds were made available to growing entitlement programs while block grant (funds to be spent at an institution's discretion) financing of state higher education diminished amidst market conditions that favored moneys flowing to the national and international corporate sectors to enhance competitiveness. This changed environment caused higher education and its professoriate to seek financing externally and eventually become more like those external organizations that serve as funding sources; i.e., as resource dependency theory would predict. At the same time, the corporate world sought new and increasingly more advanced technological products and processes to gain and maintain competitive advantage in the emerging global market place. The resultant of these activities was an intersection of academia with the marketplace. Those academic disciplines with more innovative abilities and talents became naturally favored by corporate interests seeking to develop competitive technical products; these new academic entrepreneurs moved to the periphery of academia while moving closer to the market to engage in competitive activities in the drive for external resources. Interpenetration of each organization set occurred as entrepreneurial activity in academia grew; technology transfer, so aptly encouraged by Bayh-Dole, enabled the movement of products and processes from academia to the marketplace (Slaughter & Leslie, 1997).

As noted above, market engagement by academics did not begin in 1980. Thus, Slaughter and Leslie do not consider academic capitalism to be comprised of new or novel activity. Rather, they use the term to describe the dramatic shift of academia to marketlike behavior and the observable intensification of that activity from 1980 through 1995. Although basic or curiosity driven research still occurs, the focus of academic research shifted to applied research driven by the commercial marketplace; some scholars have described this essential shift as the “marketization” of the academy with the concomitant result of less effort directly benefiting the public welfare (Slaughter & Leslie, 1997). Furthermore, this shift in kind is not accidental; the nation state’s policies, in the effort to maintain global competitive advantage, drive resources to academia with the clear purpose of stimulating economic growth in industry. Also, this resource distribution of government funding may be described as uneven at best; clearly, those sectors of academia closest to the marketplace will be at an advantage in the fierce competition for scarce resources. Additionally, some government monies may be directed to accommodate public service needs such as environmental clean up and health care (Slaughter & Leslie, 1997).

In 2004 Slaughter and Rhoades re-evaluated and further developed Slaughter and Leslie's conceptual model of academic capitalism into the theory of academic capitalism. This newer approach de-emphasizes the concept's link to resource dependency theory. They observed that boundaries between industry and academia are so blurred that the fundamental distinction between the organization and its environment (i.e., academia and the marketplace), which resource dependency theory calls for, can no longer be made. Slaughter and Rhoades note that academic capitalism is not the "corporatization" or subversion of academia by external forces; rather, it is the utilization by groups of members of the academic community of various state resources to "…create new circuits of knowledge…" that further integrate the university into the new, post industrial, global knowledge based economy (Slaughter & Rhoades, 2004, p. 1).

The ascendancy of this academic capitalism knowledge/learning regime, post Bayh-Dole, should be considered a departure from the Vannevar Bush public good model implemented by the US government after World War II. Strengthening this argument is Mowery and Sampat's review of Edwin Mansfield's research (completed in 1995) on the economic benefit of US university research, which revealed a high degree of social return on that research performed as late as the 1960s and 1970s (Mowery & Sampat, 2005). Academic capitalism argues that to an ever-increasing extent, academic research is no longer done for the purposes of basic research and the serendipitous public benefits that may follow. Instead, it is done for the purpose of commercialization and the generation of new income streams. Further, the research university is no longer an entity separate from industry. The 25 years since Bayh-Dole passage have witnessed industry paying royalty and license fees for the high tech commercial R&D provided by academia and paid for by federal funds, thus obviating the need for costly industrial labs. (Slaughter & Rhoades, 2004).

Slaughter and Rhoades would likely agree with Mowery and Sampat's above noted recognition of economic competitiveness concerns as a driver for the passage of Bayh-Dole. They add that its enactment served to feed the intellectual property (IP) stream and presented opportunity to academic players in technology transfer activities to better integrate with the new economy and further intensify "… the academic capitalism knowledge/learning regime." (Slaughter & Rhoades, 2004, p. 36). Those authors also inform us that there is, of course, a downside to this growth of the IP stream and its concentrated flow to the commercial technology arena: scientific discovery and technical knowledge move from the public to the private domain. Commercial players, driven by the need to maintain competitive advantage within their peer groups, impose data rights agreements upon their collaborative academic partners keeping partnership developed information in the private domain and precipitating a further departure from the Vannevar Bush public good model (Slaughter & Rhoades, 2004). Hence, the private good model of academic capitalism also signifies, to some extent, the sacrifice of academic freedom: that portion of the professoriate engaged in academia/industry collaborative technology transfer no longer has the ability to freely distribute discovered knowledge to the public however they see fit (Lee, 1998). Another apparent downside to technology transfer activity should also be noted. Despite the large growth of this activity across academe, university-licensing income is dominated by a small percentage of R&D projects. These "home runs" often fall into the biomedical research category; they are hard to predict and their licensing income is limited by the term period of their patents. This produces unpredictable, unstable, and difficult to forecast income streams, resulting in a clear management challenge. (Mowery and Sampat, 2001)

Environmental Research and Sustainable Development

Even before both the intensification of technology transfer activities and the development of academic capitalism, public awareness of environmental issues grew in the US. Indeed, not long before the passage of Bayh-Dole, a 1972 United Nations (UN) report, "The Limits of Growth," warned that earth's natural resources were being depleted and that there might not be sufficient resources remaining to allow the "developing world" to industrialize. Preceding that report by approximately two years, the US Environmental Protection Agency (EPA) was created in late 1970. That organization's initial charter was one of environmental clean up that utilized an "end-of-pipe" approach (i.e., clean up after the damage was done).

The United Nations report "Our Common Future" was released in 1987, adopting the concept of "sustainable development."[1] and providing the impetus for the 1992 Rio de

[1] Sustainable development defined as meets need of present without compromising the ability of the future to meet its needs.

Janerio Earth Summit which was the first global summit that brought together both global environmental and economic issues. In 1990 the US Congress passed the Pollution Prevention Act which established a national policy intended to reduce pollution at its source whenever and wherever feasible. As a result, the EPA's Office of Pollution Prevention and Toxics established "Green" programs, including Green Chemistry and Green Engineering. The Carol Browner led EPA of the early 1990s Clinton administration oversaw an elemental policy shift: the organization's focus changed from end-of-pipe solutions to pollution prevention with the idea of protecting the environment while strengthening economic development (Browner, 1993). In 1994 the EPA partnered with the National Science Foundation (NSF) to jointly fund green chemistry research, including the "Technology for a Sustainable Environment (TSE)" program. To date tens of millions of dollars worth of grants for basic research in green chemistry have been awarded with the TSE program alone funding $47 million for 164 research projects between 1995 and 2000. The growth of these "green" concepts was marked in 1998 by the publication of *Green* .

Chemistry: Theory and Practice (Oxford University Press: New York, 1998) by Paul Anastas and John Warner. That work originated The 12 Principles of Green Chemistry and provided a clear road map for chemists world wide to implement green chemistry. Also noteworthy is the 2002 release of the first college textbook devoted to "green" ideas, *Green Engineering: Environmentally Conscious Design of Chemical Processes* (Prentice-Hall, Upper Saddle River, NJ, 2002) by David Allen and David Shonnard.

While technology transfer activities intensified and the theory of academic capitalism developed, both global and national public awareness of environmental issues continued to grow; and, the principles of green chemistry and engineering evolved. By 2001, Allen and Shonnard, citing analyses of waste and emissions streams, estimated that the industrialized economies of the world utilize 40-80 tons of material per year per capita and that the majority of those materials are utilized once and discarded. The worldwide chemical industry contributes heavily to those waste and emission streams (Allen & Shonnard, 2001). Each and every product has its own life cycle beginning when raw materials are extracted or harvested from the earth and proceeds through a number of manufacturing steps until the product is delivered to consumers, used and then disposed of or recycled. Also, energy is consumed while wastes and emissions are generated in each stage of the life cycle. Green chemistry and engineering requires that chemists and engineers become stewards for their products and processes throughout their life cycles to ensure the appropriate level of ecoefficiency (Allen & Shonnard, 2001). The evolution of green chemistry and engineering over the last two decades, with the above noted emphasis by organizations such as the US EPA, has resulted in a preferred management solution for waste and emission control that calls for pollution prevention and reduction rather than post life cycle clean up. This has led to some companies embracing sustainable development by adopting a green approach to the "triple bottom line." In other words, with a green approach, the traditional economic bottom line becomes congruent with improving social conditions and conducting environmentally favorable manufacturing processes. Doing so will result in: better motivated and healthier employees (i.e., more productive) while fewer resources are consumed and less waste is generated. All of which, collectively, will improve quality and reduce costs while increasing demand (Mihelic, et al, 2003).

Exceptionally noteworthy is the significant potential for economic impact caused by the adoption of green practices: companies have found that they can actually save money over the long run by reducing chemical releases into their local surroundings since costs associated with both raw materials and waste disposal are decreased. The development of the capability to modify products and processes to achieve those types of results and producing safer chemicals requires cutting edge research and research well ahead of practice. Conducting this research are groups of chemists and engineers who have taken actions in an attempt to change to "green" the internal practices of their own profession. These chemists and engineers may be considered insiders who serve as enthusiastic actors and even leaders in the environmental movement instead of resentful or even legally mandated participants. Woodhouse and Breyman (2005) describe this group of moderate highly trained chemists, engineers and regulators as powerful participants in a "social movement." This is a small but elite group operating within a "technosphere" devoted to green chemistry and engineering for the purpose of sustainable industrial development for the sake of sustainable societies (Woodhouse & Breyman, 2005).

Regardless of their motivation, be it improved profit margin, compliance with tougher environmental regulations, or simply the betterment of society's welfare by improving the environment, companies are competing for that part of the total federal

R&D resource stream allocated for the environmental sciences. As noted above, NSF survey data indicates that approximately 5% ($2.6 billion) of the total university R&D expenditure was spent on environmental sciences in 2006. That amount is an increase from ten years earlier: $1.477 billion was spent on the same research category in 1996 (NSF, 2007). One approach to winning these monies and potentially establishing or sustaining a competitive advantage is to form partnerships with local universities to conduct collaborative research projects. Specifically, industry and academia together engage in entrepreneurial activity to conduct environmental or "green" research efforts funded, at least in part, by federal mission agencies such as NSF, EPA or the Department of Energy (DOE). An academic capitalist might suggest that such activity is undertaken by business to utilize university facilities paid for with federal funds and to leverage the human capital of the professoriate and their staffs of graduate students and technicians. In contrast, a green chemical engineer might suggest that the partnership is motivated by concern for the environment and the economy. Regardless of perspective, the partnerships may perform work with certain equipments or obtain knowledge for the purpose of process, product or knowledge development that industry would otherwise have to pay for. And, as noted above, little scholarly work has been performed to clarify this subtle or "non-traditional" form of technology/knowledge transfer. The intent of this inquiry is to fill that gap.

Although not specifically targeted, a natural product of studying these collaborative academic/industry projects was the ability to gather data concerning the benefits to students associated with team membership. In 1996 the Accreditation Board for Engineering and Technology (ABET) changed their undergraduate accreditation criteria to include the performance of students on multidisciplinary teams. To some extent that change was driven by the knowledge that industry more and more relied on teams to increase productivity; additionally, research had shown that working in groups honed communication and problem solving skills. Qualitative research demonstrated that students believed that those same skills were further enhanced if they could work with industry partners (Colbeck, et al, 2000). In 2006 ABET published a study by The Center for the Study of Higher Education at The Pennsylvania State University; its purpose was to determine what the impacts were of the primary changes to its accreditation criteria made in 1996. Findings of that study included: collaborative learning experiences were one of the most powerful influences on learning outcomes and that of employers surveyed 79% rate teamwork as highly important while 17% rated teamwork as moderately important (Lattuca, et al, 2006). Finally, research sponsored by the Carnegie Foundation has resulted in findings that clearly show that laboratory based design projects have, in general, been a missed opportunity to develop teamwork and problem solving skills that are essential keys to the development of engineering professionals. Instead, too much time is spent in the classroom learning the theory associated with engineering science and technology (Sheppard, et al, 2008). Thus, the data collected during this study has also been analyzed form the perspective of benefits to undergraduate students as members of subject collaborative teams; it is presented in Chapter Four. Unfortunately, data concerning undergraduate students was limited to one site. Hence, it was not possible to formulate definitive findings in this area.

CHAPTER THREE: RESEARCH DESIGN AND METHODOLOGY

This chapter presents an overview of the research design and its methodology. The research questions and the basic approach to the research design are presented. The participating university/industrial research teams whose environmental research projects serve as this inquiry's case studies are briefly described. That group formed the unit of analysis; how and why that group was selected and the makeup of the personnel participant pool is described. The research methods, both quantitative and qualitative, used to gather and analyze the data are also provided. Lastly, inquiry limitations and advantages, a statement of researcher positionality and the theoretical framework of the study are presented.

Research Questions

In an effort to further refine the understanding of collaborative knowledge sharing and technology transfer activities in the domain of environmental research, this inquiry has explored the following research questions:

- What is the nature of the collaboration between the members of the university-industry partnerships conducting environmental research?
- What is the motivation for each member's involvement in the university-industry partnerships conducting environmental research?
- To what extent is the collaborative environmental research project being conducted to improve the overall ecoefficiency of the firm?

Design Overview

This exploratory research project used a mixed method quantitative/qualitative case study approach to answer the research questions. The quantitative portion involved a survey of university faculty, graduate and undergraduate students and industry members of the selected collaborative environmental research teams that served as case studies. The survey participant pool was neither large nor indiscriminate; rather, it was composed of groups of individual team members purposefully chosen by each team's leader, the Principal Investigator (PI), following consultation with this researcher. Each survey participant was notified by their PI that she/he would be sent the survey and requested their participation. Only after that request was the survey sent to the potential participant pool; likely as a result of that forewarning and personal request, the survey response rate was high. The purpose of the survey was to assess the attitudes of as large a pre-identified expert group as possible toward non-traditional technology transfer while obtaining data germane to each of the research questions. The interview process was planned and executed as a follow on to the survey. As with the survey, candidate interview subjects were recommended by the project PI and interviews were only conducted after the survey was completed. That sequence was adhered to so that the interviewee would have foreknowledge of the concepts of this inquiry and consequently produce a richer, more interesting narrative for the interview. The overall two step survey/interview process and sequence held certain advantages: the survey permitted this researcher access to a wider participant pool while obtaining the broader view of technology transfer; the interview process secured more personal narratives and a deeper insight into issues associated with collaborative relationships and technology transfer.

Unit of Analysis: University/Industry Collaborative Research Teams

This investigation has limited the unit of analysis to the relationships between:

- Team personnel from the Engineering Research Center (ERC) for Product and Process Xray at Southwestern University and several different companies, including Corporations IndiaOne and IndiaTwo
- Eastnorthern University Chemical Engineering Department personnel and Corporation Mike
- Team personnel from the Engineering Research Center for Product and Process Yankee at Southeastern University and several different companies, including Corporations IndiaOne, IndiaTwo, Echo, Foxtrot, Golf and Startup Victor

(For convenience, a table of participants is presented as Appendix C)

Selection of these institutions was purposeful and clearly not random. Considerable effort and time was expended finding institutions with collaborative academic-industrial scientific research teams that are or were focused on environmental matters and willing to cooperate with this investigator. This purposeful selection was indeed a goal of this study. That goal was achieved: selected participants were able to provide insight and understanding of the phenomenon under investigation, technology transfer conducted by collaborative research teams (Bloomberg and Volpe, 2008). This researcher considered random or non-purposeful selection of university and/or industrial environmental researchers for this study to increase the volume of data collected; that approach was discarded early in the data acquisition process as it became apparent that it would be non-productive. At Southwestern, a discussion with leadership personnel following an email exchange resulted in the selection of Southwestern's ERC as a participating organization. The internet websites of scientific associations were searched for research team papers and presentations; that approach led to the selection of the Engineering Clinic program of Eastnorthern's Chemical Engineering Department. A personal friend provided an introduction to personnel of Southeastern's ERC which led to the selection of that research center. Obtaining information from each of those institutions was an unexpectedly long process; one organization required confidentiality and right to use agreement approval at the vice presidential level of the partner company. Of primary importance to the participant selection process, the leadership and their staffs at each institution and some of their industrial partners were willing to share information, despite the potential for inappropriate release of proprietary or competition sensitive information. Once general agreement was reached with the leadership of the targeted institution regarding access by this researcher, organic institutional documents such as ERC annual reports, project reports, and corporate publicity literature were obtained and reviewed to gain a top level understanding of each research project and its applicability to this inquiry. This document review process was particularly helpful for the ERC portion of this investigation, affording the selection of most apropos research projects from many candidates. Once projects were thus identified and targeted, each team's leader, the Principal Investigator (PI) was contacted to obtain project peculiar access. Due to the possibility of inadvertent release of potentially proprietary or competition sensitive information this researcher agreed with all study participants that literature and documentation obtained from them would be used only by this researcher and only for this study. In keeping with that concept of confidentiality, each institution and all participants are referred to in this document with an assigned pseudonym.

Also important to this inquiry was the attractive blend of the institutions: all three are sized differently, yet each conducts environmentally related research while performing other activities. Southwestern's (itself categorized by the Carnegie Institute as an RU/VH, a research university with very high research activity) ERC is a very large organization with many universities and industry partners participating in a wide variety of Product and Process Xray related research activities. Study participants from that ERC included faculty and graduate students. Local company personnel (Corporation Romeo Mike and Startup Tango) engaged in non-ERC research activities with Southwestern also participated. Eastnorthern University (categorized as Master's L: Master's Colleges and Universities (larger programs) by the Carnegie Institute) is a smaller institution that has developed an engineering clinic approach to research projects as part of its undergraduate and masters level engineering curricula. Integral to that clinic approach, local members of industry form a research project partner relationship at the engineering department level. Study participants from Eastnorthern included faculty and undergraduate students from the Chemical Engineering Department; local company (i.e., Corporation Mike) personnel historically partnered with that department's research activities also participated. Southeastern University is also categorized as an RU/VH, a research university with very high research activity. Southeastern's NSF sponsored Engineering Research Center (ERC), the Center for Product and Process Yankee (CPPY), provided access to research teams for participation in this inquiry; participants included faculty, graduate students and members of a local start up company, Corporation Startup Victor, all engaged in CPPY research activities.

Two of the organizations involved in this inquiry are Engineering Research Centers originally sponsored and funded by the National Science Foundation, a USG agency. There were clear and obvious similarities of focus between these two organizations: engagement in engineering research activities, funded in part by federal monies as well as an industry sector interested in a particular engineering discipline; the education of engineering doctoral students; partnering with a wide array of industrial firms and research organizations from other universities. The primary conceptual difference observed by this researcher between the two centers was the subject matter of their engineering research. Added to these two participants was the Engineering Clinic of Eastnorthern's Chemical Engineering Department with a different focus entirely: the education of undergraduate and masters students through the use of real world engineering research projects derived from a partnership with local industry. Primary similarities between Eastnorthern and the two ERCs were the focus on the education of students and the relationship with a local firm.

The research efforts of each selected university/industry collaborative effort served as its own case study. Interviews of Southwestern's ERC personnel were limited to two separate research projects due only to availability; surveyed personnel were from several projects. Also due to availability, no members of industry associated with Southwestern's ERC were interviewed or surveyed. However, further investigation resulted in survey participation of three and interview of two industry people (one interview and survey from Corporation Romeo Mike personnel and two surveys and one interview from Startup Tango) working on a Southwestern research project not associated with Southwestern's ERC. Specifically, that investigation was enabled by this researcher's employee-only access to Corporation Romeo Mike's company website; public domain information was found therein that described Corporation Romeo Mike's joint research efforts with several universities, including Southwestern. Subsequent efforts revealed project details and the involvement of Startup Tango.

Eastnorthern faculty and Corporation Mike (CM) personnel, members of several different but related projects over a three year period, were surveyed and interviewed. The Eastnorthern undergraduate student participants were involved only in the 2007-2008 Engineering Clinic project. Southeastern's CPPY ERC participating personnel, faculty and graduate students, were drawn from two separate projects. Industry personnel from a local start up company (Corporation Startup Victor), partnered with CPPY, participated in both survey and interview. The aggregate of the case study results serve to refine the understanding of the relationships between each of the partners, the cases' degree of involvement in the above non-traditional form of technology transfer, degree of usage of "Green" engineering principles, any environmental impacts and the degree to which the tenets of academic capitalism are at work with respect to each project.

Description of Methods of Data Collection

This study conducted an exploratory assessment of the results of the process of non-traditional technology transfer within the construct of collaborative environmentally related research activities. Specifically, the inquiry probed for information to address the research questions: whether or not the given process, within its stated limits, can serve the ecosystem, academia and industry and what is the relationship of the process to academic capitalism?

The approach of this exploratory inquiry was a two phase sequential mixed methods study of several cases of collaborative industry/university engineering research teams. The implementation of this methodology utilized a sequential explanatory design strategy (Creswell, 2003). The relationship between the members of each team served as its own embedded case study with the goal to determine if and to what extent it is (or was) possible to transfer real, practical engineering work to local universities while also serving the environment and the objectives of each of the academic and industrial participants. The relationships of those non-traditional technology transfer activities to academic capitalism were also explored. Both relationship sets were observed within the construct of environmental related research. And, the category itself of targeted (directly or indirectly) research, the environment, was assessed to determine if there is a special relationship to academic capitalism theory. Specifically, academic capitalism would likely posit that the research projects addressed herein were conducted with income generation as the primary motive. As this researcher’s investigation evolved it became apparent that, in the case of the academic side of each partnership, other factors were potentially serving as motivation to move research efforts forward, including the betterment of the environment. This was considered particularly interesting and probed deeper than originally intended.

A graphic representation of a sequential explanatory design strategy with qualitative methods dominant is shown below in Figure 3.1 (Creswell, 2003). An approach with qualitative inquiry dominant was considered appropriate since that methodology provided this researcher the opportunity to understand the subtle nuances of each unique team environment including elements such as workload constraints at the university laboratory and the industrial facility or office complex as well as any administrative or security concerns. Use of this approach led to data rich in the detail of normal operations at each site and has provided an assessment of the viability of the postulated subject work transfer process.

Data Collection Issue: Access

A significant issue associated with this inquiry is common to both the survey and the interview process. In fact, it has affected the entire scope of this exploratory study. Indeed, it cuts through to the basic premise of data acquisition and is directly related to the issue of access. Entry into the domain of collaborative academic/industry scientific research teams by this individual independent researcher proved challenging, tedious and simply quite difficult. Attempts at "cold" access (i.e., access as an individual without recognizable organization affiliation or without introduction from an insider or other known individual) were over 90% unsuccessful; only two of over 30 attempts succeeded. Cold access entry into the collaborative research team led by Eastnorthern University

(ENU) was successful. Additionally, a cold call to a fellow employee at Corporation Romeo Mike (CRM) resulted in access to a collaborative research team at Southwestern University (SWU) independent of the Engineering Research Center (ERC). A very large volume of communications (emails and voice mails) made to initiate entry into various university-based research teams that might have served as potential candidates for this study were left unanswered, despite repeated attempts; others were politely denied. Note that three of those approximately 30 experiences were not completely cold attempts for team access. Rather, email or phone calls from mutual associates, fellow employees at CRM who had current or previous affiliation with the subject university research personnel preceded those three particular failed attempts. All of these initial contacts were made merely for the purpose of gaining insight to supplement public (website, open literature, etc) information and thus enable the determination of whether a research project should be considered a candidate for this study. Denial of access was categorized as either explicit, meaning negative response via email or phone conversation, or implicit, meaning no response to repeated requests. The basic denial of access, whether explicit or implicit, coupled with the self imposed time constraints of this academic inquiry, clearly hampered this exploratory study: the scope of data acquisition was limited to the research communities at only three research sites. Note also that at those three sites, industry team members were somewhat more difficult to access than their academic counterparts. Further, this denial of access to even first order descriptive, non-proprietary data (i.e., the next level over web site information in the public domain) also curtailed this researcher's ability to categorize potential candidates for this study as "traditional" or "non-traditional" technology transfer projects. Thus, this researcher cannot ascribe this access issue to a peculiarity of either technology transfer category utilized in this study.

Denial of access to research teams and data acquisition limitations were not restricted to either the academic or industrial communities; rather, it was common to both. An example from the academic community comes from an experience with one of this nation's prominent academic environmental researchers (research project team leader for multiple projects, educator and author of an environmental college textbook). A detailed dialogue with that individual over the course of several months, including both email and telephone calls, led this researcher to believe that access to current environmental collaborative research projects would be granted. Unfortunately, that dialogue was abruptly ended when the subject individual informed this investigator that the industrial sponsor of the ongoing environmental research had denied access to project information; no rationale for access denial was provided. It should also be noted that during this dialogue a fellow employee at CRM who had previously worked with the targeted university researcher attempted to personally intercede on the behalf of this researcher; that attempt failed.

An industry example of access denial is also pertinent. As noted previously, research conducted on the private website of this investigator's employer led to the discovery of ongoing company research efforts with SWU; members of one of those research teams participated in this inquiry, both survey and interview. Unfortunately, access to another ongoing research project between Corporation Romeo Mike and

Southwestern University was implicitly denied: fellow employees repeatedly failed to return email and phone calls on the subject.

The general inference derived from the above noted experiential observations during the course of this investigation is: access to collaborative environmental academic/industry research teams by an independent, individual researcher is considered very difficult.

The essential reason associated with the denial of team access and data acquisition is considered to be the basic nature of the research teams: collaborative efforts between academic units and industrial firms. In that type of relationship, protection of data apparently becomes paramount; its release for even benign efforts such as this inquiry is, at a minimum, made administratively challenging by the industrial partner. This protection is applied, in general, to keep company information out of the public domain and thus, out of the hands of any potential competitors. An example of this procedure is the multi-month process this investigator experienced to obtain approval for a "Consent to Use (CTU)" agreement at the corporate vice presidential level for release of Corporation Mike (CM)/Eastnorthern research team data. That process used by CM is considered standard, cautionary and essential to satisfying legal requirements for release of proprietary information. It is, as the length of time involved in the CM case might indicate, also considered by some to be an administrative burden and one that could easily be avoided if access was simply denied on the basis of privacy. The CTU process is also familiar to and was expected by this investigator due to prior employment experiences. Unfortunately, for 90% of the access attempts made, the opportunity to go through the CTU process (or similar) was never afforded. Note that during the months long dialogue with the prominent academic environmental researcher mentioned above, this researcher repeatedly offered to go through the CTU or CTU-like process in order to gain the requisite permission for data access; opportunity was ultimately denied by the industrial partner and rationale was not provided.

Hence, the general access denial issue was most likely experienced due to the data generated by the teams and its privacy nature associated with the industry partner's concern for competitive advantage. In 100% of the cases where access was denied, a member of industry was involved in some way; whether the denial was, for each case, specifically for data protection or avoidance of administrative activities is unknown. Due to the fundamental nature of this inquiry access to academic only or academic/government research teams was not explored; access data to those types of teams is not known to be available for comparison. It is considered unlikely that denial of access to those team types would have been experienced at rates similar to the 90% rate of this inquiry.

This access denial issue, while frustrating and a limiting factor to this inquiry, was not entirely surprising. Recent education and employment experiences coupled with literature review clearly implied that privacy of data might also be considered a byproduct of academic capitalism. As discussed by Slaughter and Rhoades, academic freedom is sometimes sacrificed at the altar of technology transfer: the distribution of data for the general public good becomes subservient to the perceived private good of the industrial partner (Slaughter & Rhoades, 2004). Denial of access becomes a natural consequence. This researcher has fifteen years of industry employment experience; that background has provided concomitant knowledge of the concern of private industry for competitive advantage. That knowledge, coupled with an understanding of academic capitalism theory, made denial of access not entirely unexpected even before this inquiry commenced. By itself then, it should not be considered strikingly new or novel. However, the frequency and degree of access denial was, indeed, surprising. It was not restricted to either partner category nor was it bound by geography, type of firm or college/university size or type. The importance and implication of this observation shall be further illuminated in Chapter Five.

Data Collection, Part I: The Survey

The first phase of data collection was a survey of all participants. The survey served as a technique or tool to collect quantitative information (see Appendix A

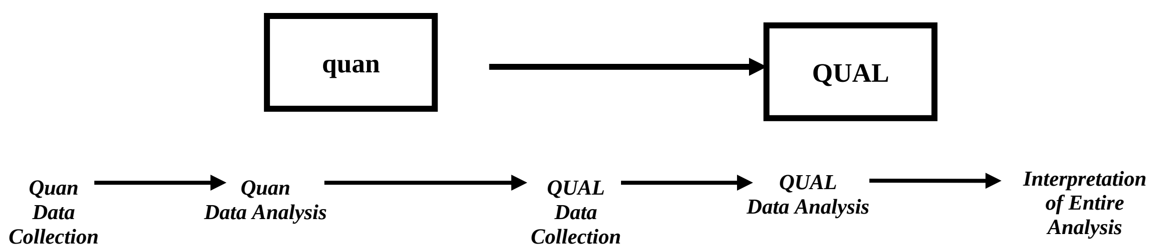

Figure 3.1. Sequential Explanatory Design

for each of the survey's seventeen questions) from its respondents. The internet survey service, QuestionPro, was utilized to develop and distribute the survey instrument. That particular internet survey service was chosen for several reasons: it was free of charge to this student researcher as part of a university wide promotional offer, ease of use of its software survey tool set for the instrument design, attractiveness and ease of use of the questionnaire for the survey participant and resultant multi-use statistical end product. The use of QuestionPro and its products permitted this researcher to distribute the questionnaire and collect response data via email and the internet. Thus, by design, the survey was self-administered by each of the survey participants. This particular approach to quantitative data collection was chosen to allow the respondents to complete the survey at any convenient time or place that internet service was available. This ease of access and concomitant ability to secure privacy were considered essential to optimize participant response rate. The survey was comprised of both open and closed ended questions. A draft of the questions and the format of the survey instrument were reviewed and modified several times by this researcher after feedback was received from dissertation committee members and other faculty from the Higher Education Department, classmates and friends; that review and edit process was facilitated by the QuestionPro service. As a result of the feedback/review process, opportunity for comments from respondents was provided as part of the survey instrument. Two principles remained constant throughout the review process and were, in fact, enhanced by that process: the survey was designed specifically for the targeted participant pool and was purposefully tailored to answer this investigation's above noted research questions.

The survey was divided into two sections, the first (Questions One through Three; see Appendix A) of which gathered participant information regarding specifics of project involvement such as organization, project name and personal position on the project.

The survey's second section (Questions 4 through 17; see Appendix A) was designed to gather data peculiar to this inquiry's research questions. The participants were asked questions intended to measure their own general perceptions of their research and their collaborative relationship experienced during that research such as: who initiated formation of the project team and what was the motivation for doing so; whether or not a project is being conducted to improve the overall ecoefficiency of the participating firm, the environment in general or for the benefit of society in general; adherence to the principles of Green Engineering; whether or not the research was designed for the explicit purpose of income generation; and whether or not work was being transferred from a firm to a university. All but one of the questions in the second survey section utilized a five point Likert scale to frame the question and each of those also provided the respondent with an opportunity to comment on the subject of the question. This opportunity to comment was added based on reviewer feedback and was specifically designed to enable the respondent's description of her/his perception of the question's peculiar subject matter. For those particular questions (6 through 12 and 14 through 17; see Appendix A) the five point Likert scale was used to measure the degree of agreement/disagreement. Opportunity for comment was provided by offering the respondent a "Please Explain" block into which narrative comments, not restricted to a given length, could be added as desired. Approval of the final version of the QuestionPro survey (including an introduction for the benefit of all participants) was obtained from the Southwestern's Human Subjects Protection Program prior to sending the survey to the actual participant pool.

The survey was sent to a total participant pool of 36 people; as stated above, all participants were notified in advance that the survey would be sent. Of that group, 30 participants responded for a total response rate of 83%. Eleven members of the Southwestern University community (faculty, graduate and undergraduate students and two members of local firms) were sent the survey; ten responded, producing a response rate of 91%. Sixteen people associated with Eastnorthern University, including faculty, undergraduate students and seven employees of Corporation Mike were sent the survey; 12 responded, producing a response rate of 75%. Nine members of the CPPY community at Southeastern University, including faculty, graduate students and one employee of Corporation Startup Victor were sent the survey; eight responded, producing a response rate of 89%. Table 3.1 provides a tabular summary of the survey response rates.

The composition of the survey respondent group included subjects from each organization's engineering leadership structure, people responsible for all operations in their respective areas; this included research Principal Investigators (PIs) and their staff. This was a purposeful choice; those personnel were explicitly targeted since they possess

Table 3.1: Survey Response Rates (by university community)

	Sent	**Responded**	**Response Rate**
Southwestern University	11	10	91%
Eastnorthern University	16	12	75%
Southeastern	9	8	89%
Total	**36**	**30**	**83%**

sufficient management as well as functional area knowledge and expertise that permitted them to assess the viability of this inquiry's subject work transfer process. Student participation included two graduate students from Southwestern's ERC, four undergraduate students from Eastnorthern and four graduate students from Southeastern. The pool of student participants was, as expected and planned, limited to those actually working on the subject projects or recently departed but still available. The survey participant pool was also subdivided into four different groups by respondent category, which cut across the three university communities: faculty, graduate students, undergraduate students and industry personnel; this sort of the survey data is shown in Table 3.2 below.

Description of Methods of Data Analysis, Part 1: The Survey

Data from the questionnaire was generated in Excel format automatically by the QuestionPro survey service. All the data was useable; all questions were answered by every survey respondent.

Table 3.2 Survey Response Rates (by respondent category)

	Sent	**Responded**	**Response Rate**
Faculty	10	9	90%
Graduate Students	6	5	83%
Undergraduate Students	8	5	62%
Industry	12	12	100%
Total	**36**	**31**	**86%**

An overview of the entire sample was completed: descriptive statistics for the total respondent pool were obtained and are presented in Chapter Four. Descriptive statistics from each of the three communities comprising the respondent pool were compiled and compared. The data was further divided for additional comparisons: faculty from each community; students from each community; all industry and all faculty respondents.

Data Collection, Part II: The Interviews

The second phase of data collection was the interview process, the primary method of data collection in this study. Selection of interview subjects bore some similarity to the selection of survey participants: all interviewees were either research project Principal Investigators (PI) or recommended by their PI. Eleven semi-structured interviews were conducted. Interviews consisted, other than personal and position related demographic information, of open ended questions (see Appendix B for initial interview questions) intended to guide the interview subjects to respond freely with their own opinions on issues germane to this inquiry. Similar to the process of survey instrument definition, a draft of the interview questions was reviewed and modified several times by this researcher after feedback was received from dissertation committee members and other faculty from the Higher Education Department, classmates and friends. As a result of the feedback/review process, interview questions were better focused and this researcher was better prepared to conduct the interview process. Like the survey, the open ended interview questions were designed specifically for the targeted participant pool and were purposefully tailored to answer this inquiry's research questions. Approval of the final version of the interview questions was obtained from the

Southwestern's Human Subjects Protection Program (HSPP) prior to sending the survey to the actual participant pool. Further, in keeping with HSPP policy, an "Informed Consent" form was signed by each participant prior to the beginning of every interview and then filed for safe keeping. After each interview was conducted, a personal note of thanks was sent to each interviewee.

All interviews were captured on audiotape after permission to do so was granted by the interview subject; however, due to geographic location of the three research sites and this researcher's home location, seven of the eleven interviews took place via telephone and six people of that group of seven were never met in person by this investigator. All interviews for both the Eastnorthern and Southeastern communities fell into this category. This physical separation during the interview process was considered less than optimal by this researcher and will be discussed further in the findings section of this inquiry.

First phase survey results were, to the maximum extent possible, reviewed prior to beginning the interview process. The original intent was to conduct and review all surveys before conducting any interviews. The purpose of that approach was to use the knowledge obtained from a complete review of all surveys to gain greater insight into the subject matter and thus be a more intelligent interviewer with a better optimized set of questions to guide the interview process. Due to the availability of the participants and other logistical challenges, that approach proved impractical. Rather, collected survey results up to the day before each interview were reviewed to assist in the interview process; the utility of this approach, in general, proved limited. However, review of the individual interviewee’s survey before each interview was completed and proved helpful in determining aspects of the subject matter the participant was most interested in or felt strongly about (positively or negatively). As noted above and in keeping with recommendations by Creswell, documents germane to each project were reviewed prior to each interview, contributing to a richer and fuller dialogue with the interviewee (Creswell, 2003). Additionally, whenever logistics permitted, subsequent interview questions were sometimes modified or enriched based on results of completed, transcribed and reviewed interviews. Armed with that knowledge the interviewer could then attempt to guide the interview in the desired direction or simply spend more time on particular questions than others by probing deeper for more detailed information.

As stated above, the interview questions were, in general, designed to provide information germane to this inquiry’s research questions. Specifically, questions were developed to inquire regarding: the extent to which the participants believed their research project was collaborative with their partner; origins of the research project; income streams; technology transfer opportunities; project impact on the environment in general and a firm’s ability to use the project to facilitate their compliance with government environmental regulations; and the project as a recruiting tool.

The last item, “project as a recruiting tool,” framed by the last interview question from the approved set provided this researcher with surprising information. Only through deep probing, enabled as outlined above by foreknowledge garnered from review of both survey response data and completed interviews, could that information have been developed. That subject will be addressed further in Chapter Four, the findings section of this inquiry.

Description of Methods of Data Analysis, Part II: The Interviews

The initial plan of this researcher regarding analysis of interview data called for analysis to take place concurrently with data collection. This early and continual analysis approach was intended and expected to help in the collection of better data by cycling through old and new data and adjusting tactics and even strategies based on preliminary findings. Specifically, future interview questions were to be modified based on analysis results of completed surveys and interviews. As noted above, due to the busy schedules of the interview process participants, availability was limited, and the concurrency concept proved impractical. Consequently, full/complete data analysis did not occur during the interview process. Rather, survey results and prior interview transcripts were read and notes were made to enable the conduct of the next interview to be better focused: probes were fashioned and tactics refined and the interview process evolved as it progressed through the eleven participants.

In general, Creswell's six generic steps to data analysis and interpretation were used as a guide for this study's review of its qualitative interview data (Creswell, 2003). Creswell's Step One calls for the organization and preparation of the data. Accordingly, following the transcription of interviews, interview participants were categorized by: site, engineering research project and position; administratively, this was accomplished by using that information as header data for columns in an Excel spreadsheet. Creswell's Step Two recommends reading through the transcriptions "… to obtain a general sense of the information …" (Creswell, 2003, p 191). Thus, interviews were initially analyzed by reading and rereading the transcripts while underlining/highlighting interviewee comments to get the general sense of things considered relevant to both research questions and the survey questions and open-ended comments. Using that initial review of the interview data as well as the above noted document review, the coding process (Creswell's Step Three) was begun. Codes were formulated with this information and used to build a data matrix using the Excel spreadsheet started in Step One: each interviewee was assigned one column of the spreadsheet with the pertinent identification information in matrix cells immediately below each name. As the interview data was read and reread codes were further developed with keywords and phrases germane to this inquiry identified, developed and inserted into the spreadsheet's matrix. Note that these codes were used to assign meaning to words or groups of words that are pertinent to the study, such as: "collaboration," "technology transfer", "income stream", "environment", "recruiting," etc. The codes were intended to represent a summary of thoughts or ideas. Each of these codes was assigned rows by placing them vertically in the first column of the spreadsheet. This coding process evolved with the progression of the analysis through the interview transcripts: codes were added as each transcript was analyzed and some already existing codes were revisited and modified to better capture a concept. After all transcripts were analyzed and codes entered into the matrix, they were all reread; this iterative process was accompanied by filling in the intersecting cells (interviewee column with code row) with a chosen color, producing a checkerboard effect that permitted a quick visual assessment of which codes were common and to what degree amongst interviewees. In the midst of that process, two columns were added to the matrix: one for research questions and one for survey questions. The intent of that addition was to use researcher judgment to determine whether a particular code was relevant to any research or survey question and then display it graphically for ease of correlation. Following those two steps, the interview transcripts were then revisited and interviewee quotes pertinent to a given code were extracted and inserted into the matrix at the correct column and row intersection. This was done for two reasons: add greater depth to the utility of the matrix and enable easy access to quotes for the findings section of this inquiry. Additionally, that review of the transcripts, coupled with the build up of the spreadsheet and its concomitant utility, enabled the development and selection of themes or categories in the data (Creswell Step Four) to be used as findings for this inquiry. Creswell's Step Five was loosely followed by developing the narrative associated with the findings section of this study. Interpretation of the qualitative data, Creswell's Step Six, was then performed; that process included reflection on this researcher's personal beliefs and experiences with the broader engineering community. Conclusions were reached, lessons learned were recorded and new questions were raised.

Validity

Noteworthy in this inquiry is the triangulation of data enabled by the multiple data sources. This triangulation served as the primary strategy to check and validate the accuracy of this inquiry's findings. This process was conducted by correlating the different data sources. On the purely qualitative side, interviews from different and geographically separated sites were correlated; additionally, responses to the open-ended survey questions were correlated to other survey responses and to interview data. Correlations occurred among: faculty at one site with those at another site, academic personnel to industry personnel (intra and inter team), and faculty to students. As suggested by Bloomberg, quantitative survey data was also used for triangulation purposes: survey question data was correlated with interview information and open-ended survey responses (Bloomberg and Volpe, 2008). These correlations served to enhance the overall data analysis and to consequently enrich the findings and conclusions of this study.

Limitations and Advantages

As with most qualitative research, the generalizability of the findings of this study is limited. The study was restricted to personnel from three universities and associated partner firms. The specific organizations at two of the targeted universities were National Science Foundation sponsored Engineering Research Centers; at the third university, the Chemical Engineering Department was this study's subject. Partner firms for each university organization were also part of this inquiry. Extrapolation of the findings to other firms or institutions is likely best suited to similar organizations: university and industrial members of the subject and/or other ERCs and engineering departments seeking to establish an engineering clinic similar to that of Eastnorthern.

The unit of analysis was clearly quite limited; the research activities of only three universities participated in this inquiry's survey and interview process. Two reasons that caused this limitation were:

a. The research activities sought as case studies were limited to those that featured both a collaborative relationship between academia and industry and a focus on environmental matters. The size of the candidate set meeting those criteria is unknown; experientially it is thought to be small. Considerable time and effort was expended researching potential candidates.

b. Once a collaborative research project was identified as a candidate case study, the project's Principal Investigator had to agree to freely exchange information with this researcher. Accomplishing that in an environment that included information of a potentially sensitive and industrially competitive nature proved problematic and served to severely limit the size of the candidate set. A more precise treatment of this problem is provided in Chapter Four, the findings section of this inquiry.

As both a member of the university community from which one of this inquiry's case studies was drawn and as an engineer employed by one of the companies (Corporation Romeo Mike) that provided both survey and interview participants, this researcher was, to some extent, considered an insider. Both of those insider roles were considered advantageous by and for this researcher. As a member of the local university community of one of the participating institutions (Southwestern), this researcher was, to some extent, granted access to its research teams out of professional courtesy. Similarly, access to this researcher's fellow employees engaged in a research partnership with that same local university was first initiated through employee-only access to the company's website; interview and survey participation would likely not have been granted to an outsider. In both cases, this researcher, as an insider, clearly had advantage over an outsider. That advantaged position was not considered abnormal; however, special care was taken to maintain a clear sense of objectivity while gathering and analyzing data (Brayboy and Deyhle, 2000). That same insider position may also have been a limitation; as an insider, knowledge of the engineering culture may have influenced the omission or misinterpretation of data. The advantage of access was considered to far outweigh any limitation posed by insider status.

Positionality

This researcher is a practicing engineer educated in both engineering and business. I am employed by a very high tech and profitable defense industry firm (Corporation Romeo Mike); one current and one recent employee of that same defense company, engaged in non-ERC research activities at Southwestern University, were interviewed and surveyed for this study. I also attend the local university as a part time doctoral student in a field quite different than that of my earlier engineering educational experiences, the study of higher education systems; several survey and interview participants are members of the same university community.

I have worked as an engineer in the defense industry, in both government and industry sectors, for approximately twenty years; additionally, I have recently assumed program management responsibilities. I hold considerable bias toward the practical and prompt resolution of difficult engineering and management problems. However, that type of demanding approach, frequently coupled with impatience and an intolerant attitude, was deliberately avoided with great care during the course of this study. I anticipated working with research teams composed of people with a wide variety of personalities, skill levels and temperaments with exceptionally demanding schedules; I was not disappointed. A lack of patience or a demanding attitude would have doomed this project.

During the course of this exploratory study I became aware of the very difficult nature of the problems faced by today's environmental researchers, not only technical but also personal, financial and administrative. I believe my experience and basic understanding of general engineering and business process, coupled with a much tempered personal approach and attitude, served this project well. Clearly, my natural extinct to seek quick answers to challenging problems would not have succeeded with the chosen participant pool.

Theoretical Frameworks

The primary theory used in this mixed method case study inquiry was Slaughter and Rhoades' 2004 academic capitalism theory (see above for origin details). Case study data, from both survey and interviews, have been explored to determine the extent of non-traditional technology transfer and how it fits into the commonly understood framework of academic capitalism. It should be noted that academic capitalism touches on numerous aspects of academia other than the selling of research products via the technology transfer mechanism described herein. The full framework of academic capitalism in today's knowledge based, post-industrial economy includes marketing and selling of many items other than the fruits of government sponsored and funded research. Within the academic community, organization structures have been established with management and staff to perform functions such as the marketing and selling of educational services, athletic events as well as many branded and common consumer goods (Slaughter & Rhoades, 2004). From the standpoint of this researcher, academic capitalism theory will be used as the lens through which to view the activities that serve as the subject of this inquiry. However, that lens, for this investigation, has been focused on the income generation of academic researchers; specifically how it fits within the fabric of academic capitalism theory.

CHAPTER FOUR: FINDINGS

This chapter provides the findings from the data analysis of this exploratory inquiry. The raw data from both qualitative and quantitative sources, interviews and survey respectively, have been organized, managed and analyzed so that the total collection of gathered information can be transformed into meaningful inferences. The purpose of this chapter is to arrange and present in a logical manner the findings made from those inferences. Interpretation of those findings is presented and connections made where appropriate; supportive data and references to literature are provided as necessary. In general, an integrated approach will be taken to the presentation of the supporting data for each of the findings: qualitative information will be woven together with quantitative. Each type of data supports the other with the qualitative considered to be slightly dominant. The intent of this approach is to provide the chapter with a more holistic view of the data, the general approach recommended by researchers Bloomberg and Volpe (Bloomberg and Volpe, 2008).

Findings of this inquiry are presented in five sections with each section addressing a separate analytical category. The first section discusses a general finding associated with the concept of researcher access and data acquisition. The second part presents data and interpretation regarding the nature of the collaborative relationships between the partners engaged in technology transfer activities associated with the subject case studies; the type of transfer activities is also explored. The third section discusses motivations for case study involvement while the fourth part presents the case study relationships associated with their general research topic, the environment. The fifth section addresses the importance of student participation on the subject research teams and student relationships to each of the teams' partners. The chapter concludes with a summary of the inquiry's five findings.

Collaborative Partnerships

The subject matter for this inquiry was intended to be drawn from collaborative university/industry teams engaged in scientific research on environmental matters; technology transfer was expected to be standard procedure on that type of team. To that end, it was considered important to first establish the nature of project partnership and whether or not the project actually contained any and what type of technology transfer activity. As noted above, "traditional" technology transfer occurs when scientific research is performed in academia to develop commercially attractive technologies while industry develops the requisite industrial strategies to exploit them in the marketplace. Further, this researcher defines "non-traditional" technology transfer as an activity during which industry transfers work to academia.

To address whether or not the participants considered the nature of their projects to be collaborative the interview subjects were asked that question directly. Eight of eleven (73%) interviewees responded positively to this question with comments that included:

> "Well, the program is truly collaborative. It was formulated -- even the project initially was formulated in collaboration with industry. … So it is truly collaborative." (Head of ERC at Southwestern)

> "… the second largest … research corporation, they sent an employee here with PhD degree doing research with me. Working in my lab, yes. That is part of this project." (ERC Faculty Team Leader at Southwestern)

Those comments, from academic leadership personnel at Southwestern are supported by these comments from two industry members:

> "Well, yeah, it's a good collaboration -- strongly collaborated, yeah. The university, I think, is the foundation on which it all rests." (Corporation Romeo Mike Team Leader at Southwestern)

> "I think it's very collaborative ... and we rearranged our goals and schedules and that ... trying to make sure that what they're doing lines up with what we're doing…" (Corporation Startup Victor Team Leader at Southeastern)

Considered equally important to the nature of project partnership was whether or not the project actually contained any technology transfer activity. Establishing the fact that technology transfer activity was part of each research project was also directly addressed in a formal interview question. All interview participants considered their projects to be an example of technology transfer. A sample comment on this subject comes from an ERC Faculty Team Leader at Southwestern: "… a product is the most easily identifiable form of technology transfer, but specifically in my case, a process is a more applicable idea of what's really being transferred."

Of yet greater importance to this study was to establish the type, or the nature, of the given technology transfer activity; specifically, could the activity be considered of the non-traditional form described above wherein work is transferred to the university. There is evidence, from both the interviews and the survey, which is directly supportive of the fact that work transfer is occurring from industry to its university partner. When asked directly during the interview if their efforts involved a transfer of work from the firm to the university, eight of eleven (73%) interviewees explicitly stated that the university member of the partnership is accomplishing work for their industry counterpart. Of further interest is the fact that this type of work transfer has different motivations. It must be emphasized here that although work is being transferred to the university environment it is being done for a variety of reasons. Various interview comments illustrate the extent of this work transfer practice and the attendant motivation:

a.) As indicated by the ERC Faculty Team Leader at Southwestern, the water treatment process is being developed by SWU due to the fact that its corporate partner has chosen not to engage in that type of technology development, not because they were incapable: "…we're transferring the knowledge and developing equipment so that they can use it up there. .... The nature of the problem is coming from them and the solution to the problem is coming from us. … They're not in the water treatment business. -- they know nothing about water treatment…"

b.) As pointed out by Corporation Romeo Mike (CRM) Team Leader at Southwestern, CRM has chosen to transfer work to SWU in order to forego a capital investment: "…Yes. Yes. Definitely. They are doing work that we could not do here, at least not without a bigger investment in capital …"

c.) Startup Victor has chosen to transfer work to Southeastern so that it does not have to develop (or purchase) the competency that work requires. The president of that company reported: "… because we have them working on … some of the things we would've done in-house …… and it allows us to concentrate on some of the other things we need to do. So, yeah, there's certainly a certain amount of work that gets done there because of the funding and otherwise would've been done here." Note that the motivation of Startup Victor is clearly reflective of the literature on the subject. As described in Chapter Two, Santoro and Bierly have observed that in a global economy, firms will trend toward the reduction of their basic core competencies to sustain competitive advantage; instead they will depend on the network of supporting partnerships formed with universities/institutions (Santoro & Bierly, 2006).

Similarly, the survey served to triangulate by also providing data supportive of the fact that industry chose to engage in the activity of transferring work to academia. Asked to what extent their project could transfer engineering work from industry to participating engineering schools, the majority (50%) of the survey participants responded positively to this question and 37% were neutral. These results are shown graphically in Figure 4.1 below. An open-ended survey response from an employee at Corporation Mike, teamed with Eastnorthern: "The Eastnorthern work was effectively transferred to the company and is being used routinely." The head of the ERC at Southwestern provided this comment: "This project is in partnership with industry and transfer is continuous." All faculty members (9 of the 30 survey participants) save one were either positive or neutral on this survey question. The one exception was the Co-Director at Southeastern's ERC; however, he recanted that survey input once the question was clarified during the interview. Further, during the interview that same Co-Director was asked: "... small firms and some of the medium sized firms as well -- who don't wanna develop a particular core competency -- go to a University for that core competency work that they choose not to develop …?” The Co-Director responded: "Yes." That is certainly not a particularly interesting nor detailed response. However, when considered in full context, that type of response concerning competencies for the transfer motivation is, again, clearly reflective of the pertinent literature (Santoro & Bierly, 2006).

Interview and survey results were also indicative of which member of the collaborative research team initiated the relationship. This is considered germane since this investigator assumed that the initiator of the project was more likely to be the organization seeking something from its potential partner. Interviewees were asked how their organization first got involved in their project. The majority (eight of eleven or 73%) of that group replied that industry had gone

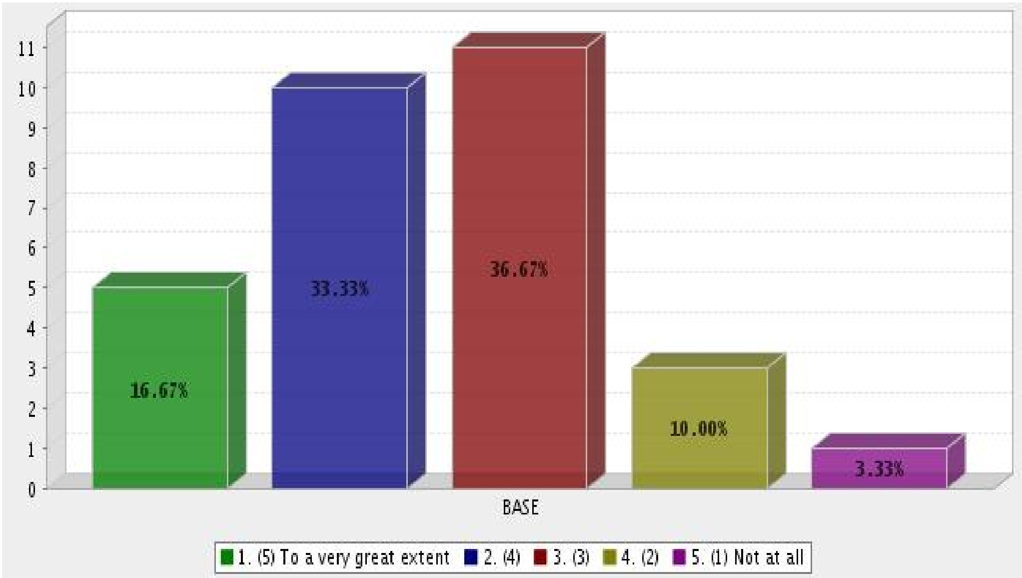

Figure 4.1 Survey Responses to Question 7: Transfer of Work from Industry to Academia

to academia to initiate the collaborative research project. Similarly, the survey also addressed this issue by simply asking which participant initiated formation of the project team. Survey results showed that the majority (19 of 30 or 63%) considered industry to have initiated team formation. Two responses of "Other" were provided, one of which was from the faculty leader of the research team at Eastnorthern who added the comment: "Joint effort between Industry and University." Salient comments on this particular subject from interviewees include the following from faculty researchers:

> "So the statement of need came from industry; the idea generation came from us." (Head of ERC at Southwestern)

> "So just having that flagship banner, people will come here with a problem and that's how we got this project. They knew about the center." (ERC Faculty Team Leader at Southwestern)

> "Okay. This project was initiated by the industry companies. Initially, it was proposed by IndiaTwo so in the year 1997 IndiaTwo … to find their power solution for the future ... processors." (ERC Faculty Team Leader at Southeastern)

And those comments from the academic side are clearly supported by the following interesting statement from an industry member (Corporation Romeo Mike Team Leader at Southwestern) regarding how he decided to go to Southwestern for the solution to a particular problem:

> "Sometime back one of the students that was working at the university getting a degree was hired by Corporation Romeo Mike and I met that student and was discussing the topic of *technology X* and said that, you know, I thought that was an interesting topic and might have some applications at Corporation Romeo Mike and, you know, could he put me in touch with that professor? He did and that was perhaps five or six years ago and so we've been working on these ideas ever since and the amount of activity has steadily increased."

Clearly, technology transfer activity can take different forms and is performed for many different reasons. Noteworthy is the following study participant's (Co-Director of ERC at Southeastern) interpretation of technology transfer activity that this researcher considered particularly interesting and, perhaps, even novel:

> "... from University to industry happens through graduate students ... as they graduate and they go and work in the industry. I think the ideas and approaches and the generic new technologies on how to do the things, that's what they carry with them and that's what they apply in industry and I think that's the broadest and most intense technology transfer that happens."

One of this study's research questions inquired into the nature of the collaboration between the members of the university-industry partnerships conducting environmental research. Data from the coding and categorizing process clearly supports the fact that the partnerships involve the industry team member transferring work to its university. However, it is not supportive or clear that it is doing so because industry could not do the transferred work itself. Consequently, the finding derived from the interpretation of the pertinent data is simply: industry participants have chosen to have their university collaborative research project team partners accomplish work for them. Further, it does indicate that industry sometimes partners with academia specifically to have academia perform work for the purpose of process, product or knowledge development that they would otherwise have to pay for were they to perform the work themselves. This is considered a subtle difference in motivation from that posed by the research question. Regardless of that difference, the data does show that industry has, when practical and/or as necessary, departed from the traditional form of technology transfer and adopted collaborative practices with academia that result in technology transfer activities that fall into the previously defined category of "non-traditional" technology transfer.

Project Motivations

Another research question sought the extent of motivation for project participation attributable to the development of new income streams for the participants. The clear purpose of that question was to discover the extent to which the participants were motivated by the principles of this inquiry's theoretical framework. However, since the participating collaborative research teams (groups comprised of industrialists, engineers and engineering students) were not expected to be cognizant of the theory of academic capitalism, the question was asked about income stream generation, not the theory. Note that the above mentioned education and employment experiences predisposed this researcher to consider the interviewees and survey participants to be fully engaged in academic capitalism: marketization of academia for the purpose of income generation. Further, for the purpose of full disclosure and openness, the access issue experienced early in this investigation only served to enhance that predisposition. That bias was, to the greatest extent possible, held in check at the start of the interview process; it faded quickly and became a non-factor for the academic interviews shortly after that process began.

The survey addressed this important subject by asking the participants explicitly for their basic motivation behind the given research project. Possible answers were: "Scientific Discovery," "Generate income for parent organization" and "Education."

Respondents were permitted to choose all answers that applied; they were also given the opportunity to comment in the "Please Explain" box provided for open ended responses.

The 30 survey participants provided 46 responses to the first question: the “Scientific Discovery” option was selected by 18 participants, “Generate income for parent organization” was chosen by 15 participants and the “Education” option was chosen by 13 participants. Responses from the nine faculty participants included eight “Scientific Discovery,” three “Generate income” choices and five choices of “Education” (See Table 4.1 below). Two of the three faculty members who made the “Generate income” selection also chose both of the other two options. One of those two faculty members provided this comment: “In all cases, motivation was 'trilateral'. Students receive academic credit for Engineering Clinic -- thus the academic experience is paramount. The project met technical needs of the company - i.e., working on a process that would save time/money, produce purer product, reduce waste, etc. University benefits in terms of faculty expertise, funding, and equipment.” The “… save time/money…” concept portion of this comment referring to the motivation for industry involvement warrants further attention. This concept was mentioned several times during the interview process and is considered to be an approach familiar to this researcher based on prior employment experiences: cost avoidance. Although industry’s involvement in the collaborative research team efforts does not, in some cases, appear to be for the direct purpose of “new income stream generation,” industry does engage to save time and/or money which will clearly avoid costs and result in greater revenue, although not necessarily “new streams” of income. Thus, the industry team members, by using these collaborative research activities with academia to enhance their bottom line were clearly involved in activity that could fit under the umbrella of academic capitalism (Slaughter and Rhoades, 2004). The 12 industry participants selected "Scientific Discovery" five times, "Generate income" 8 times and chose "Education" three times. Results from this survey question (Survey Question Five) are provided graphically in Table 4.1 below. A second survey question also addressed the income generation issue by seeking the extent to which the dominant motivation for executing a research project was the generation of new income streams for the participants. Over 55% of the responses to that survey question were positive, with 20% indicating that income was the dominant motivation "To a very great extent." Grouping respondents in

Table 4.1 Survey Response to Question Five, Project Motivation

	n	**Scientific Discovery**	**Generate Income**	**Education**
Faculty	9	8	3	5
Students	9	5	4	5
Industry	12	5	8	3
Total	**30**	**18**	**15**	**13**

the same manner as that done for the previous question provides a different view of this data. Three faculty members selected positive responses, four were neutral and two provided negative responses. Nine of the 12 industry members of the survey participant pool selected positive responses, one was neutral and two provided negative responses. Six of nine students provided positive or neutral responses and three were negative.

Results from this "income is dominant" survey question are provided graphically in Table 4.2 below. The faculty team leader at Eastnorthern added this comment: "My dominant motivation is to provide a meaningful academic experience for the students, in which they work with industry partners and learn in a real-world, project-based environment. It is important to me to maintain a successful relationship with our industrial partners, so their interests are important to me too." A comment from an industry member, who provided the only strongly negative survey response from that sub-group, is particularly thought provoking: "Would be cost saving not generating new income stream." As noted above, this comment showed again that participants are not necessarily interested in generating new income streams but are concerned with additional revenue; in this case by new methods of cost avoidance. Another interesting comment comes from a student at Eastnorthern who provides one of three strongly positive responses from that sub-group: "The project was designed for the plant to make a profit and save money. The project was designed to further establish links to the university to help all those involved. The goal of the project was not for the students to make money or the university however." The Corporation Startup Victor Team Leader at Southeastern provided this comment concerning income generation as a goal: "This is very much our goal as we plan to transition the university work to product development in short order."

The interview process was intended to ask whether the participants' collaborative project should be considered a new source of income. This question was explicitly addressed in seven of the eleven interviews; implicitly, it was addressed in all eleven.

One of the implicit comments came during the interview discussion of the process of technology transfer with the Corporation

Table 4.2 Survey Response to Question Five, Income as Dominant Project Motivation

	n	To A Very Great Extent	(4)	(3)	(2)	Not At All
Faculty	9	2	1	4	1	1
Students	9	3	1	2	0	3
Industry	12	1	8	1	1	1
Total	**30**	**6**	**10**	**7**	**2**	**5**

Romeo Mike Team Leader at Southwestern: "… a company like Romeo Mike needs it or can use it, sees a way to … make a profit with it and another organization such as a university has developed foundations for that product … and … Romeo Mike interfacing with say that university research group, they can learn about it and understand what's needed to turn it into a useful product." Additional explicit comments that support the concept of project as income generation include the following comments from faculty researchers:

> "My perception is if this technology were fully rolled out and used in all IndiaTwo facilities, in all the places it could be used, they could be saving quite a lot of money from utility type costs right off the top." (ERC Student Team Member at Southwestern)

> "I have no doubt that industry is giving us money for the reason to include the solutions and the knowledge that comes out of this project into their future product in order to make money. Yes. I don't think they're doing this for, well, they might be good hearted but they're giving us money in order to make money. Yes." (Co-Director of ERC at Southeastern)

Those faculty comments are supported by inputs from both student and industry, as shown in the following comments:

> "If you reuse some water that will save the money to the industry and also it will save the water which they use, which can be used by the community. So that combinations -- like this is fundamental so by that combination, if you use -- if the industries want to use it then they can save a lot of money." (ERC Student Team Member at Southwestern)

> "I think in the long term, yes, we hope that the products we're working to develop will eventually develop into a source of income for us, yes." (Corporation Startup Victor Team Leader at Southeastern)

The above data clearly support this finding concerning motivation for project involvement: Generation of additional income is the prime motivator for industry involvement in collaborative research teams with academia.

There was equally clear, yet very different, motivation for project involvement on the part of the academic partners. Note that two of the research sites involved in this inquiry are Engineering Research Centers initially established by the National Science Foundation. NSF's goal for all ERCs is: "The goal of the Generation Three (Gen-3) Engineering Research Centers (ERC) Program is to create a culture of innovation in engineering research and education that links scientific discovery to technological innovation through transformational engineered systems research in order to advance technology and produce engineering graduates who will be creative innovators in a global economy." Thus, one of the stated goals of the organization that established and sponsored the ERCs has always been the education of students.

As noted above during the discussion that established industrial involvement in the collaborative team concept, the survey asked for the basic motivation behind the research project. Again, possible answers included: "Scientific Discovery," "Generate income for parent organization" and "Education." As noted in that discussion, five of nine faculty participants selected "Education." By itself that quantitative data, although representing a majority of faculty members surveyed, was not considered strongly supportive of education being a prime motivator for project involvement. However, when the noted accompanying open ended comments (e.g., "…the academic experience is paramount …") to that question's responses are considered, this investigator judged the responses to this survey question to be supportive of education as a prime motivator. Another survey question approached the concept slightly differently: "To what extent can the research project serve the education goals of the university participant?" In this case, the responses to the survey question were overwhelmingly positive: 93% positive, 7% neutral and no negative responses. Those results are clearly strongly supportive of education as a prime motivator for academic involvement on the collaborative research teams; results are provided graphically below in Figure 4.2. The faculty team leader at Eastnorthern provided this compelling comment: "…Most remarkably, employer feedback consistently indicates that our students demonstrate independence and ability to tackle new problems without a large degree of 'hand-holding' in comparison to students who do not have a similar experience…" From industry, a member of the Corporation Startup Tango team provided this comment: "Numerous degrees are anticipated to be completed during this project, in addition to future academic research." Finally, and perhaps most telling, was this comment from the Co-Director of the Southeastern ERC: "… The only reason we have projects is to provide environment for educating graduate students in conducting research."

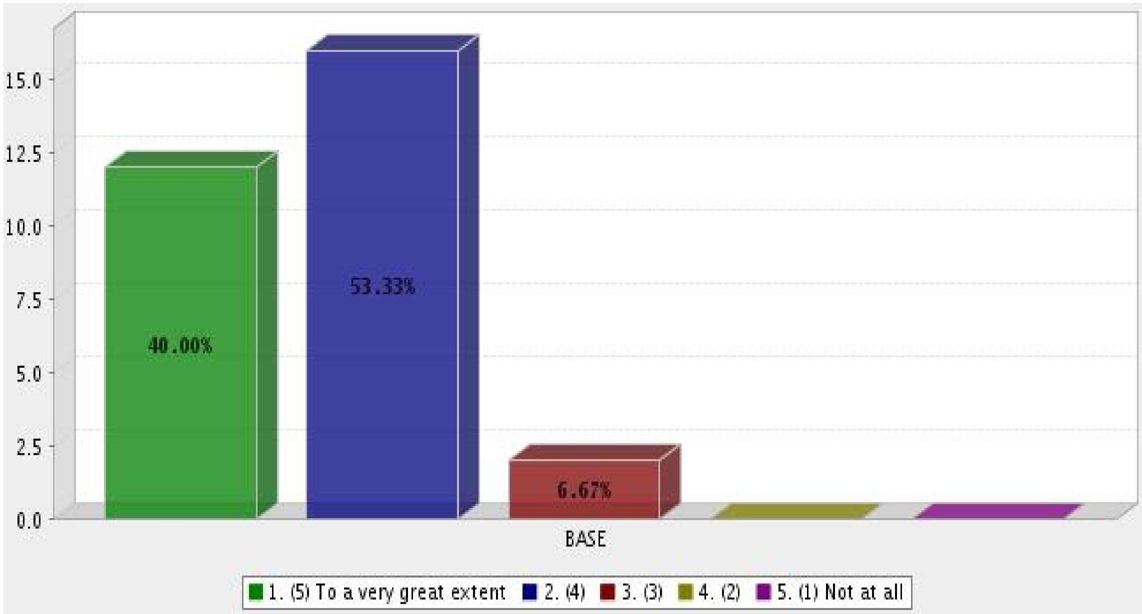

Figure 4.2 Survey Responses to Question 16: Research Efforts Serving Education Goals

Note that these survey results were not expected. Academic capitalism theory would predict that the academic partner, attempting to move closer to the market, was very interested, if not primarily so, with the generation of income. Once the interview process began, the matter was quickly clarified (Slaughter & Rhoades, 2004).

There were no pre-planned or formal interview questions that directly addressed whether or not education was a prime motivator or benefactor for the academic partner engaged in the subject collaborative environmental research projects. However, during the interview process and subsequent analysis, it became dramatically apparent that the participants from academe considered education to be the prime motivator for their involvement in both the subject research projects and their partnership with industry. The transcribed interview statements support this observation and it was reinforced by this observer's perception of voice inflection and body language during both telephone and face-to-face interviews. This attitude was particularly dominant with academic leadership personnel; examples include:

> “The reason I’m at the university is that our primary clients are students. We are training manpower. We are training researchers that can do a lot of things for industry. But we wanted to work on relevant problems as a part of that training. So what we do here has multiple clients. The primary client is the students.” (Head of ERC at Southwestern)

> “… it was and it was source of income for the Center in order to support the research and support the graduate studies in the Center … put a little bit more, general to support us in educating those students … because the only thing I’m really producing is graduates.” (Co-Director of ERC at Southeastern)

> “So part of the purpose of this is not 100% for technology but still education. But we also make sure that some part of this research the graduate student will benefit from it for education, for training for the student.” (ERC Faculty Team Leader at Southwestern)

> “…what we are doing here are very interesting to the student and also the project we’re doing here can raise the money for us so that we use it to support the student.” (ERC Faculty Team Leader at Southwestern)

All of the above data are clearly supportive of another portion of the motivation finding: education was considered a prime motivator and benefactor for the academic partner involved in the research projects that served as case studies for this inquiry. This finding is not intended to mean that the generation of income through project involvement is not a motivating factor for academic engagement. Rather, income generation is a concern and a motivational factor, but not the primary one. In the cases studied, the reason for academic concern with income generation appears to be motivated by the strong desire to secure adequate support for the education of students, both graduate and undergraduate. The subject projects appear to have embraced the marketplace due to lack of sufficient fiscal support from their parent institutions for the purpose of furthering their mission; industry funding is secured for support of students and/or purchase of research equipment. Although the tenets of academic capitalism are served as the case study partnerships move academia closer to the marketplace while new income streams are generated, these actions appear to be for the betterment of higher education. Zemsky describes this type of academic behavior as "… being market-smart to remain mission-centered …" (Zemsky, et al, 2005, p. 9). The 2008/9 world wide economic recession has put this type of behavior into current and sharp context: in the United States, state government support of public higher education institutions is, in some instances, decreasing; some dramatically so. In some cases, endowments are shrinking as well. Thus, some academic actors will be more likely to embrace the market to secure funding simply to achieve mission goals. As the Faculty leader of the research team at Eastnorthern revealed in an interview: " Yeah, yeah, these are funded projects and they provide money for equipment, and equipment of course is related to the project, but often we find use for it after the end of the project and we've used some of the equipment either for other projects or for classes, so students benefit from that." Academic researchers, like those at Southwestern and Eastnorthern, will move closer to the market in a smart manner to secure new sources of income in order to stay on mission: educating students. Additionally, and as a beneficial byproduct, new learning opportunities are fostered such as teamwork on real world industrial projects at Eastnorthern.

A final comment from an interview with an industry participant further serves well the point of education as a prime motivator for academe involvement: "…where's the student topic in that work, you know, 'cause we need to make sure there's a unique, interesting academic interest, topic, that the student can make sure that they get a degree." (Corporation Startup Victor Team Leader at Southeastern)

Intuition and some amount of tangential evidence suggest that the efforts of all the participants would be motivated to some degree by environmental concerns. Simply due to the subject matter of this inquiry, it is apparent that all participants were engaged in projects that in some way involved environmental matters; some quite successfully. However, that involvement alone does not necessitate motivation.

The Engineering Research Center at SWU includes the following words in the title of the organization: "Environmentally Benign … Manufacturing." The vision of that ERC includes the creation of the science, technology, and educational methods to lead its targeted industry to a new era of environmentally benign manufacturing. Additionally, its stated goals include: the development of novel strategic solutions to existing environmental, safety and health (ESH) problems in manufacturing; the creation of new and effective environmentally benign manufacturing processes; and the development of innovative education programs in which environmental factors are integral parts of the curriculum.

The ERC at Southeastern includes as part of its vision the development of concepts that contain next-generation energy efficient and environmentally friendly applications. Also, the stated goals of that organization include the exploration of viable and innovative opportunities for industrial applications such as alternative energy, more energy efficient and cleaner transportation.

Thus, it can be clearly stated that both Engineering Research Centers strive to have environmental matters serving as a research focal point with and for their industrial partners. Those organizational policies are suggestive of the fact that their researchers are probably motivated to perform research that serves the environment for the sake of the environment. A small amount of interview evidence, such as voice inflection and body language suggested that was the case. However likely the environmental motivation may be based on the above evidence is an unknown; there has been insufficient data gathered to support it as a finding. That is especially true in light of the other, established findings on the subject of project motivation. Collaborative research projects are apparently focused on the environment as the current target of opportunity due to today's plethora of environmental funding from federal mission agencies. As stated above, motivation of team partners is primarily additional income for industry and education for academia. Within the case studies investigated, research on the environment for the sake of the environment is likely, at most, a secondary motivation for some team participants. Unfortunately, environment as motivation for a project was not an explicit or implicit question in either the survey or the interview process. This topic will be further addressed in Chapter Five.

The Environment

The impact of the research projects on the environment, addressed specifically as a research question that inquired into the ability of a project to improve the overall ecoefficiency of the firm, was addressed both in the survey and during the participant interviews.

During the interviews the participants were asked whether or not their research project was beneficial to the environment and if the project served to improve the participating firm's ecoefficiency and/or its compliance with government regulations. The interview process provided overwhelmingly supportive evidence that the environment is clearly a focus for all the researchers involved in this study. The most succinct yet clearest response on this subject came from a faculty project team leader at the Southeastern ERC. When asked if he considered his project to be helpful to the environment, he responded: "Of course." Other comments concerning project affect on the environment include the following from faculty researchers:

> "The nature of this project is somewhat different. We are developing the technologies which lead to development of the products which will then enable society to save energy … technologies so that aircraft could be more efficient…" (Co-Director of ERC at Southeastern)

> "This project is very clear. The benefit of it to environmental is so visible. You don't have to -- it's not convoluted. Now if you say we are going to reduce the water usage by a factor of three or four, I mean, it's so obvious." (Head of ERC at Southwestern)

> " ... the projects I am doing are related to environmental friendly manufacturing process; not the treatment of the waste. It is my focus -- my interest is the process makes it green. The idea for this is you want industry to be -- you want people -- industry guy to be interested, you need to bring in something they want. So you want to say this is also a benefit for you. For example, my idea is low consumption -- low water, low energy consumption. In this way the industry also benefits from it. So they would like to do it so this is kind of a win-win situation for us. I want the environmental benign, you want money so we can you know join together and do something good." (ERC Faculty Team Leader at Southwestern)

Those faculty comments are further supported by these comments from an industry team member and a student:

> "Yes. I think it has a huge impact because of the area we're working in has to do with ... I don't know, being able to make renewable and more green, more efficient use of electricity in all kinds of different ways. Yeah." (Corporation Startup Victor Team Leader at Southeastern)

> "And from this difference we were getting about like 40% or 50% about water savings and about 30% to 40% energy savings. So yes, by using our sensor and successful implementation of optimization of the recipes they can sure -- the industry can surely save a lot of water. Yeah, huge environmental impact." (ERC Student Team Member at Southwestern)

The survey approached the environmental subject by asking the participants two different Likert scale questions. The first survey question asked the participants to posit to what extent they expected their research efforts to serve the ecosystem (i.e., the environment in general). Responses to that survey question (Question Six) included 60% positive and 23% neutral (25 of 30), clear indication that the majority of the participants believe that their research efforts served the environment. These results are depicted graphically in Figure 4.3 below. A particularly pertinent comment comes from the faculty team leader at Eastnorthern concerning the work her team has done while teamed with Corporation Mike: "Process improvements lead to reduction of waste, replacement of process materials with more environmentally benign ones, and purer product that requires less downstream processing." A team leader from Corporation Mike offered this comment: "Student projects sponsored by the company are very closely associated with sustainability initiatives being undertaken by the company." A student at Southeastern, who provided a neutral answer to the survey question, added this input: "The project is oriented towards environment and renewable energies. The gains, however, from this project may not be significant to serve the ecosystem, but it should serve as a small step in that direction." Clearly that input can be interpreted to mean that the student's project was intended to affect the environment.

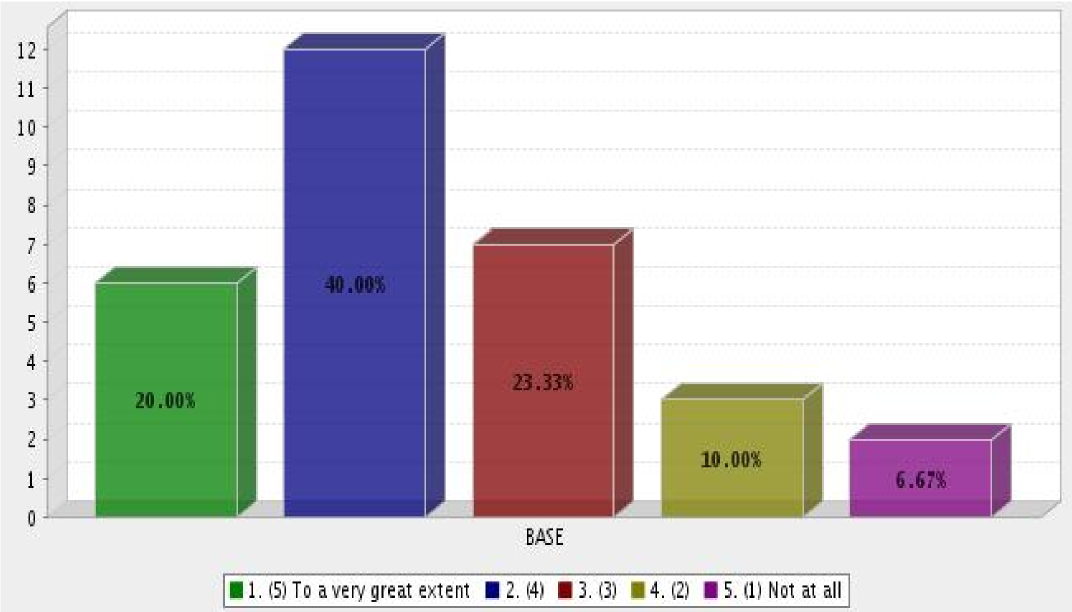

Figure 4.3 Survey Responses to Question 6: Research Efforts Serving the Ecosystem

The second germane survey question (Question Eight), then attempted to gain insight into project environmental efforts from a more narrow focus: it sought the extent of firm ecoefficiency as a result of project efforts. The responses to this question provide a slightly more positive overall response than to the previous question: 63% positive while 10% were neutral (22 of 30); again, a clear indication that the majority of the participants believe that their research efforts will serve the environment, in this case by improving the participating firm(s)' ecoefficiency. Both survey questions resulted in positive majority responses: Question Six (the more general question) had 25 of 30 (or

83%) in the neutral or better categories while Question Eight had only 73% in those same categories. These results may, at first, seem slightly incongruous. However, considered from the perspective that a given research project may serve the environment, even if serendipitously, but not the environmental objectives of the given firm (the more narrow objective) and both response categories are taken into account, then the minor disparity is considered logical.

Faculty responses to survey Question Eight included six of nine positive (67%), one neutral and two negative. Industry responses included seven of 12 positive (58%), no neutral and five negative. These results are depicted graphically in Table 4.3. A student at Southwestern captured the main environmental friendly thrust of his research project with Corporation IndiaTwo: "The whole point is to help IndiaTwo's bottom line by reducing fresh water intake and chemical usage. An industry member of the research team at Southeastern added this comment: "… the project wants to reduce the usage of fossil fuels for electric generation and increase the utilization of wind solar and geothermal …"

Table 4.3 Survey Response to Question Eight, Research Efforts Serving Ecoefficiency of Firm

	n	**To A Very Great Extent**	**(4)**	**(3)**	**(2)**	**Not At All**
Faculty	9	2	4	1	1	1
Students	9	4	2	2	0	1
Industry	12	3	4	0	2	3
Total	**30**	**9**	**10**	**3**	**3**	**5**

The above evidence that result from the coding and categorizing data from the interview process coupled with data from the survey, has provided clear and very strong support for the following finding: the environment, either explicitly or implicitly, is served beneficially as a research focus point in all cases involved in this study.

Impact on Engineering Students

During the course of this inquiry the recruiting practices of both industry and academia were investigated. It was found that both industry and academia utilize their participation in collaborative environmental research projects as a recruiting tool. The fact that industry was engaged in that activity was not unexpected; the extent and intensity of its involvement was considered quite surprising. One of the survey questions asked to what extent the industry partner used the research effort as an employee recruiting tool. Responses to this question were supportive of the fact that industry has utilized their project involvement as a recruiting tool: 50% positive, 27% neutral and 23% negative. Even more informative were the comments provided with the responses to this question, particularly from the Faculty Team Leader at Eastnorthern, who stated:

> “Several students have been hired for full time employment, part time work, or summer internships…”

Further independent reinforcement of the concept of the project as a recruiting tool comes from that team leader’s corporate counterpart as well as industry personnel from another investigation site:

> “Students participating in sponsored projects are given opportunity to work at the company outside of the project. This allows students and company alike to evaluate each other relative to potential employment after graduation.” (Corporation Mike Team Leader at Eastnorthern)

> "…I hope to be able to retain the students we are working with, provided things progress as expected." (Corporation Startup Victor Team Leader at Southeastern)

Attempting to triangulate the above noted survey data with interview information, each interview was concluded with the following pre-planned question: "To what extent do you consider the project work accomplished by the university personnel to have served as a recruiting tool for your company?" The responses to this question were considered strongly supportive of the research project being used as a recruiting tool. Germane comments included several similar to those above regarding recruiting of graduating students (undergraduates and graduate) by industry. However, also included were the following comments reflective of university using these collaborative research projects as a recruiting tool to attract graduate students. The leadership of the ERC at Southwestern provided the following two comments:

> "So when they see the center program, when they see that we are working on these relevant problems and industry cares about it then they are attracted to apply to come to graduate school. … They compare different programs and they want to go to a graduate program where there is a good potential for employment, the problems are real. (Head of ERC at Southwestern)

> "…good place to work in and if you want to get hired by the semiconductor industry get yourself on a project that involves that and 95% of those people wind up going to work for one of the people sponsoring the project." (ERC Faculty Team Leader at Southwestern)

Those two comments from the organization's leadership were, in fact, supported by the following comment from one of their students:

> "The reason that I came here was because of this center and this project. If not because of this center or this project I'd probably be in Connecticut or in some other place." (ERC Student at Southwestern)

A similar comment from the Southeastern ERC serves to triangulate the data concerning the concept of these collaborative research projects serving the university as a recruiting tool to attract graduate students:

> "We use our projects and description of that to both recruit future projects so to have continued funding for education as well as to recruit future students who will be educated. Yes." (Co-Director of ERC at Southeastern)

Using the above data, the process of coding and categorizing resulted in the following finding: the student recruiting processes of both industry and academia (graduate level) were served by the collaborative environmental research projects that acted as case studies for this inquiry.

Additionally, the following two comments were of particular interest and constituted information considered exceptionally revealing by this researcher:

> "For most companies that support our research, recruiting is the major goal." (Co-Director of ERC at Southeastern)

> "I mean, sometimes a project may not even be of any interest. It's more of a trial by fire to see how well that student can handle a design or handle his work or be able to present his work or her work and by the time you've done that .... this person really can handle it and is really worth bringing in and so that's, it's ,,, better than paying headhunters in some instance … the student is often the product" (Corporation Startup Victor Team Leader at Southeastern)

These two comments, made by the leadership personnel of both industry and academia, certainly imply that the recruitment of employees is, at times, more important than the research project itself. Serving as triangulation for the above information is this voluntarily offered input by the Co-Director at the Southeastern ERC with no knowledge of the above comments from Southwestern: "For most companies that support our research, recruiting is the major goal." Hence, one can postulate that a research project may be established, despite costs involved and with the full knowledge of academic leadership, for the actual (vice stated) purpose of evaluating and attracting students as future employees. This information was considered of great interest, providing evidence sufficient to modify the above formal finding concerning recruiting to read: the student recruiting processes of both industry and academia (graduate level) were served by the collaborative environmental research projects that acted as case studies for this inquiry. In some instances, the principals involved considered recruiting students to be more important than the research project itself.

The above comments were made at Southwestern and Southeastern where all student participants were graduate students. However, the faculty team leader at Eastnorthern provided this compelling comment concerning her undergraduate students: "…Most remarkably, employer feedback consistently indicates that our students demonstrate independence and ability to tackle new problems without a large degree of 'hand-holding' in comparison to students who do not have a similar experience…" This very interesting data coupled with knowledge of the appropriate literature on the subject has resulted in the interpretation that the collaborative teamwork engaged in by students (graduate and undergraduate) has made them more attractive job candidates to prospective employers than peers without team experience. Reasons for that position are likely enhanced teamwork, problem solving and communication skills, all considered highly valuable by industry due to their perceived positive impact on productivity (Lattuca, et al, 2006).

Chapter Summary

This chapter presented a holistic interpretation of the gathered data, resulting in six findings. Summarizing those findings:

Finding 1. Industry participants have chosen to have their university collaborative research project team partners accomplish work for them.

Finding 2. Generation of additional income is the prime motivator for industry involvement in collaborative research teams with academia but the rationale underlying their choice varied. In contrast, education was considered a prime motivator and benefactor for the academic partner involved in the research projects that served as case studies for this inquiry.

Finding 3. The environment, either explicitly or implicitly, is served beneficially as a research focus point in all cases involved in this study.

Finding 4. The student recruiting processes of both industry and academia (graduate level) were served by the collaborative environmental research projects that acted as case studies for this inquiry. In some instances, the principals involved considered recruiting students to be more important than the research project itself.

This mixed methods study gathered data from interviews and an internet based survey. Typical of qualitative research, extensive samples of participant interview quotations are included. In this report additional quotations were provided from the survey; open-ended questions afforded this opportunity. This approach was utilized to provide the participants' own words to better capture an accurate representation of reality. Substantive supporting quantitative information was drawn from the raw survey data and served well in strengthening several of the key findings of this study.

The primary finding of this inquiry is considered to be that academia utilizes their involvement with industry in collaborative environmental research projects to support what remains their number one goal: the education of their students (Finding 2). This was a repetitive and dominant theme throughout this study. It was well supported by both interview and survey data at both the graduate and undergraduate levels.

Another finding indicated that additional income generation is a prime motivator for industry (Finding 2). Additionally, industry has used this type of collaborative research project to transfer work to their academic partner (Finding 1). Finding 3 is a finding that was also considered important to the nation's citizenry: the environment is being beneficially served as a research subject of all subject case studies. Finally, the projects observed during this study all serve as a recruiting tool for both industry and academia and in some instances, the principals involved considered recruiting students to be more important than the research project itself (Finding 4).

CHAPTER FIVE: IMPLICATIONS AND RECOMMENDATIONS

This chapter summarizes the inquiry, provides implications of the study's research findings and presents recommendations for future research.

Study Summary

The purpose of this mixed methods multicase study was to explore the relationships between academia and industry during the non-traditional transfer of technology or knowledge products and processes within research teams formed between a firm and a local university. The central focus of this inquiry was environmental research at college and university engineering schools. The environmental selection itself was purposeful: foreknowledge of the large amount of federal and state government research expenditures within the environmental arena led this researcher to consider that domain a fertile ground for this exploratory inquiry. Despite the apparent abundance of potential teams for this investigation, finding teams that would cooperate and provide data access proved difficult. A limited sample of only three research sites was found with established collaborative industry/academic environmental research teams that would, most importantly, cooperate with this researcher. Information obtained from the investigation of these teams was used to develop knowledge concerning the extent to which the collaborative efforts of the teams served the project researchers, industry, students and the environment.

Qualitative data was collected by conducting eleven in-depth, semi-structured interviews; supporting quantitative data was collected by utilizing an internet-based marketing/polling service to conduct a survey of over 30 subjects. The participant pool was composed of faculty (including Principal Investigators), members of industry and students from the three different and geographically separated sites.

This investigation was based on the following research questions, which served as the primary basis for organizing, coding and analyzing the gathered data:

- What is the nature of the collaboration between the members of the university-industry partnerships conducting environmental research?
- What is the motivation for each member's involvement in the university-industry partnerships conducting environmental research?
- To what extent is the collaborative environmental research project being conducted to improve the overall ecoefficiency of the firm?

These three central research questions were addressed in detail by the findings developed above in Chapter Four. As stated, this researcher considers the primary finding of this effort to be that, regarding the observed cases, academia is involved with industry mainly to serve their overriding objective: the education of students. While investigating the above research questions, other findings concerning data access and student recruitment practices were identified. The complete set of findings included:

Finding 1. Industry participants have chosen to have their university collaborative research project team partners accomplish work for them.

Finding 2. Generation of additional income is the prime motivator for industry involvement in collaborative research teams with academia but the rationale underlying their choice varied. In contrast, education was considered a prime motivator and benefactor for the academic partner involved in the research projects that served as case studies for this inquiry.

Finding 3. The environment, either explicitly or implicitly, is served beneficially as a research focus point in all cases involved in this study.

Finding 4. The student recruiting processes of both industry and academia (graduate level) were served by the collaborative environmental research projects that acted as case studies for this inquiry. In some instances, the principals involved considered recruiting students to be more important than the research project itself.

Concomitant with the primary finding noted above, an apparent theme revealed during this investigation of relationships between members of the subject collaborative research teams is that education remains the primary goal of the academic segment of those partnerships. Note that this recurrent theme by itself provided a limited lens through which to view the data. The theory of academic capitalism was also clearly relevant to each case: academics moved closer to the marketplace and income streams were generated. However, that movement towards the market, for the observed case studies, deserves careful characterization; it was neither frivolous nor purely commercially driven. Rather, it should be considered smart or even wise for it took place to generate income that enabled the academy to stay centered on mission: student education.

The following advantages were observed in the research projects studied:

- The generation of value for each of the project partners

- Furthered the education of graduate and undergraduate students
- Benefits to the public good in terms of the environment

In contrast, denial of access, was the only significant disadvantage observed in the research projects studied. The general denial of access, coupled with one project's time consuming data release process experienced by this researcher, are indicators that, to a largely unquantifiable extent, the academic capitalist theorists are correct: the marketization of academic research comes with a price tag attached. Academic movement toward the marketplace is accompanied by the impedance of the flow of information generated within academia. The free flow of academic data into the public domain as called for by the Vannevar Bush model of the World War Two era has become constrained. As observed by this exploratory study, the competitive forces of the market contain the flow of data to the private domain. To a very large extent, data generated by the team members of a research project stays within that project's membership. The cost associated with this practice is academic freedom; it is considered the single observed significant disadvantage associated with the university/industrial partner relationships that served this inquiry.

With due consideration of advantages and disadvantages, implications for further research are addressed below.

Research Implications

A significant implication of this research is one relevant primarily to the academy and is neither new nor novel. This inquiry has shown that technology transfer, in multiple forms, does work and has done so since the early twentieth century. In fact, the

Bayh-Dole Act, enacted in 1980, served as an enabler but not its originator. Academic capitalism applied theory to its practice. Further, for the observed case studies, technology transfer, when applied wisely, can work to serve the mission of the academy. Note that it was also shown that the very same technology transfer activity could and likely does serve the collaborative industry partner by generating value. The implication is put into still sharper terms when the 2008/9 economic climate of a US recession is considered. Government support of academe will more likely decline than remain static; it is possible that technology transfer can be utilized to make up some of that fiscal support. Specifically, an implication of this study is that the transfer of work from industry to academia (i.e., non-traditional technology transfer) can be used to further the academic mission. That type of activity, as academic capitalism suggests, is clearly more applicable to those academic disciplines already close to the marketplace such as the engineering centers that cooperated with this researcher. One should also note the clearly successful example of Eastnorthern. That institution’s relatively small chemical engineering department has teamed with local industry to engage in non-traditional technology transfer activities. In so doing, Eastnorthern has completed real world engineering projects that have taught its undergraduates how to work in multi-disciplinary teams while favorably impacting the environment and serving the needs of its industry partners. All of that was accomplished while generating income streams for the university that have been used to purchase equipments that can be utilized for current and future projects. Also noteworthy are the disadvantages associated with this type of technology transfer. The flow of information from, for example, the Corporation

Mike/Eastnorthern partnership was certainly constrained and thus limited process improvements developed by Eastnorthern to implementation by only Corporation Mike. Additionally, it is possible that the time spent by university researchers involved in the subject partnerships may have been expended on other research, teaching or service opportunities that might have provided greater benefits to their parent organization, students or society. Other alternative and perhaps more attractive or rewarding environmental research projects may have been pursued but were not possibly due to lack of funding (internal or external). Industry financing may have provided support for both research activities and students but not for the academic researchers' primary choice of research topics due to the motives of the provider. Alternative projects may have resulted in greater utility of the researchers' efforts and could be considered an opportunity cost for the technology transfer activity actually engaged in. However, that perspective presents an entirely new set of potential disadvantages as well.

Specific implications for industry are varied. The data clearly show that in the case studies of this inquiry, non-traditional technology transfer provided value to the industry partner either as revenue, cost savings or services. The top-level implication, of course, is that there is value to be realized by industry from partnering with academia on environmental research projects. However, care must be taken to establish relationships with the right partner for a purpose that makes sense for both participants; each member of the partnership should have reason to consider a contemplated union to be beneficial. As the literature indicated as a likely practice, the very small entrepreneurial company, Startup Victor, used the services of Southeastern to perform core competency work that it would have had to otherwise develop on its own. The successful partnership of Corporation Mike (a large company) with Eastnorthern focused on improvement of processes by utilizing teams composed primarily of undergraduates that resulted in benefits for both partners. At the same time, it would have been inappropriate for Corporation Mike to consider Eastnorthern as a sole source for a core competency. What one company may consider significant and impactful may be viewed by a different sized company as inconsequential. The specifics of what worked for Startup Victor/Southeastern would not have been considered relevant for Corporation Mike/Eastnorthern. Additionally, the projects studied were collaborative. To be successful the partners needed to work together. Southwestern consulted with its industry partners and jointly conceived and planned its project before funding was applied. Researchers were exchanged and mutual site visits were made; work was performed as a team, not by Southwestern researchers in a vacuum. Eastnorthern team members met with their Corporation Mike counterparts weekly for consultation and status reporting. Startup Victor personnel were present in the Southeastern lab facilities almost daily. Different approaches were adopted at each site; yet, success was demonstrated by the subject projects through teamwork between collaborative partners. The application of funds to a novel environmental project conducted solely by the academic portion of the partnership does not ensure success. Rather, teamwork coupled with the exchange of ideas and resources is more likely to produce a successful partnership. The implication for industry is that if a partnering approach with academia is considered as a candidate for a solution to a particular environmental problem, funding alone does not make a partnership and will likely not guarantee a successful project. A potential disadvantage to funded partnerships that requires consideration by industry prior to engagement is project failure. As with any other business opportunity, some level of cost benefit analysis that determines degree of involvement should precede corporate involvement based on potential benefits. Partnerships may result in research projects barren of value to the industry team member. Company funds may be expended with no tangible return on investment: no useful information, producible product or process improvement may result from a failed project. Also note that even a failed project may result in some benefit to the industrial partner: students may be recruited from a failed project and/or involvement may result in favorable public relations for the company. Thus, project failure presents another potential disadvantage to technology transfer partnerships; again, however, that disadvantage is considered unquantifiable. Only access to the detailed programmatic (i.e., cost, schedule, technical) information associated with a particular project could provide the full measure of disadvantage associated with project failure.

When discussing the impact of one of his projects on the environment, the Director of the Southwestern ERC provided the following quote during an interview: “Now if you say we are going to reduce the water usage by a factor of three or four, I mean, it’s so obvious.” That quote becomes much more meaningful when put into the proper context: the Director is referring to water usage during a manufacturing process that currently consumes thousands of gallons of water per day at one site located in a southwestern US desert area. A multinational corporation that owns and operates similar sites in the same region and many more around the globe owns the facility. The potential favorable environmental impact of that type of fresh water savings is clearly very large by anyone's measure should the industry partner decide to apply the approach across the region or perhaps throughout all of the corporation's international facilities as well. The implication of such an obvious beneficial result is that it is not just the engaged partners that can be served by collaborative environmental projects. Although student education will be served due to industry funding and industry will realize a cost savings due to reduced water usage, of far greater importance to society is the favorable impact of the project on the environment. Clearly, this collaborative project has the potential to serve the public good. Although of less compelling impact, projects observed at Southeastern and Eastnorthern also had favorable environmental effects: reduction in electrical power consumption at Southeastern and waste stream reductions at Eastnorthern. At each of the three different sites, academic/industry partnership projects demonstrated three combined and synergistic results: income or value was generated for both partners, students were educated, and the public good was advanced. These results are considered impressive as they constitute an across the board "triple win" for the engaged parties. Although this researcher believes each of the subject collaborative partnerships present winning situations for each partner and society, it would be presumptuous and likely imprudent to assume similar successful results as pre-ordained for future, similar projects. From a different and broader perspective, these observed projects could be used as additional evidence in support of the Bayh-Dole Act as a watershed event due to the fact that it enabled the expenditure of tax dollars on academic research to more optimally benefit the

US consumer. Of course, even with these observed “triple win” cases there is an underlying potential disadvantage. If the project specific data were available in the public domain still greater benefit to the public good might result if other companies were to adopt and implement the project results.

Although none of the three projects in question were funded directly by US Government mission agency resources, both ERCs were originally established by NSF. The implication of these results is that Bayh-Dole, which enabled the proliferation of technology transfer activities across the spectrum of US universities, served the public good, at least to some extent. And, some would argue, today’s environment is the best possible place for that service. This service of the public good implication should be tempered with the knowledge some in academe are driven to engage in technology transfer activities only to generate income needed to replace that portion of funding reduced or eliminated by cuts in government allocations to university budgets and still others are engaged in technology transfer solely for personal gain, monetary or otherwise. Furthermore, the literature on the subject shows other potential problem areas associated with technology transfer activity. Despite the large growth of this activity across academe since Bayh-Dole passage, that part of the developed income stream produced by licensing revenue is dominated by a small percentage of R&D projects. These “home runs” often fall into the biomedical research category; they are hard to predict and their licensing income is limited by the term period of their patents. This produces unpredictable, unstable, and difficult to forecast income streams, resulting in a clear management challenge (Mowery and Sampat, 2001). The implication for potential participants in university/industry collaborative partnerships pursuing transfer technology in environmental matters is to proceed cautiously: the effort required to generate actual revenue may prove non-trivial.

In general terms beyond the above noted project team specifics, Slaughter & Leslie have argued that after Bayh-Dole the focus of academic research shifted from basic to applied research as driven by the commercial marketplace and that this essential shift to the "marketization" of the academy is accompanied by less effort directly benefiting the public welfare (Slaughter & Leslie, 1997). Similarly, academic capitalism theory, as presented by Slaughter and Rhoades, has informed us that research is done primarily for the purpose of commercialization and the generation of new income streams. Note that all of those activities serve to feed the intellectual property (IP) stream (Slaughter & Rhoades, 2004). These greater amounts of data would generally be considered beneficial if useful knowledge is produced. In the case of technology transfer, the flow of information is likely toward the commercial technology arena and thus, scientific discovery and technical knowledge move from the public to the private domain to maintain the competitive advantage of the engaged industry partner. As noted previously, this researcher experienced great difficulty when attempting to gain access to information generated by industry/university collaborative research teams. Denial of access occurred repeatedly despite the fact that no proprietary technical data was sought and that competition sensitive matters could and would be honored and maintained. Two reasons are postulated for those denials: concern (or fear) regarding the release of competitive data into the public domain and subsequent acquisition, discovery and implementation by competitors or, more simply, avoidance of the administrative burden associated with approvals of release of the team specific data. Regardless of the reason for the many denials, the implication is clear and is directly supported by the data from this inquiry: academic researchers teamed with industry on environmental research projects may be prevented from public release of their research results due to the competitive sensitivity of their industry partner.

An excellent example to further understand the relationship between academic capitalism and technology transfer is the growth and activities of a particular type of the organization structures referred to by Slaughter and Rhoades, the Technology Transfer Office (TTO). The TTO was specifically established to serve as a focal point to foster and facilitate technology transfer activities and the concomitant generation of income for academic institutions. TTOs manage the patenting and licensing activities of universities. As academic capitalism would predict, Mowery and Sampat report that a situation not uncommon within today's TTOs is the tension between maximizing licensing income while maintaining the deepening relationship between faculty inventors and industrial firms (Mowery and Sampat, 2001). In 1980 there were only 25 TTOs; by 1995 there were well over 200. This growth occurred due to the fact that Bayh-Dole greatly simplified the process of patent application and industrial licensing. (Mowery and Sampat, 2001).

Today's university TTO performs market like functions such as solicitation of reports (disclosures) from faculty inventors, assessment of the commercial value of inventions, filing of patent applications, finding potential industrial licensees, and executing/monitoring license agreements. Further, TTO personnel consider themselves to be the agency responsible specifically for the implementation of Bayh-Dole. Additionally, this tension builds as they find themselves necessary to balance the interests of institution administrators with the faculty inventors who often prefer conducting sponsored research to the objectives of the administration. Lastly, TTO technology managers believe that the vast majority of licensed university inventions are so embryonic that inventor cooperation and involvement in further development is critical to the successful commercialization (i.e., marketization) of the product (Jensen and Thursby, 2001). The downside of this type of organization structure (TTO), from an academic capitalism perspective, is captured quite well by Greenberg: “Little attention given to … academic-commercial links, such as corporate secrecy invading the halls of science, conflicts of interest, monopolizing of important diagnostic tests and therapies, and diversion of scientists and students to trite moneymaking chores.” (Greenberg, 2007, p. 61). This exploratory inquiry has attempted to look at both the upside and downside of technology transfer activities through the focused lens of academic capitalism theory. This researcher considers this type of “tension” in the TTO between maximizing licensing income while maintaining the deepening relationship between faculty researchers and industrial firms (see above) reported by Mowery and Sampat in 2001 and alluded to by Greenberg (see above) in 2007 as entirely possible and a likely development of the marketization of the academy as foretold by academic capitalism theory. The above noted growth of university TTOs and university-sponsored patents, as well as this investigation’s difficulties with data access are considered general indicators that this tension is possible and point to the ascendancy of academic capitalism. However, this investigator, for the programs investigated, found no direct evidence of this type of tension at the individual program level. Rather, the functionality or demands of the technology transfer office at each of the research sites was never mentioned in any survey or interview response. The reason for the lack of participant input on TTOs may have been that no direct questions were ever planned or asked regarding that organization. However, rich discussion was conducted regarding income generation. At no time did any of the academic participants mention any unwarranted pressure from any institutional organization to generate income, TTO or otherwise. The only indicator of any type of tension, however slight, was the mild frustration expressed by Eastnorthern's lead researcher concerning the data release process required by Corporation Mike. No clear and noticeable revenue related tension, between institutional administrators and academic researchers, was observed during the course of this investigation. The fact that this trait was not found in this investigation would appear to contribute to a challenge to the tenets of academic capitalism. However, as indicated by Finding 3, academic participants were concerned with income generation, as academic capitalism clearly predicts. This investigation has found that the impetus for that concern was motivated by the desires to advance the academic goals of parent organizations; no evidence was uncovered that pointed to income generation being motivated by undue pressure from administrative personnel. The lack of this type of tension is considered more likely a result of the winning nature of the programs investigated and the personnel engaged therein rather than academic capitalism theory not being served.

Recommendations for Further Research

This inquiry was limited to three sites where industry and academia were teamed to perform collaborative environmental research. Further research should expand that rather small sample set to include several additional cooperative research teams in order to increase confidence and credibility in the results. Denial of access presents a barrier to any such sample size growth. Phone calls and/or email methods of gaining entrance to prospective team participants did not prove particularly useful in overcoming the access issue. Successful access to Eastnorthern resulted from investigation of conference presentations found at a professional society website followed up with email to the presenter. Of many attempts using that technique, Eastnorthern was the only success, likely attributable to a highly engaging and cooperative group at that institution. Southeastern access was obtained only after intercession and the persistence of a personal friend and professional colleague. Access to the researchers at Southwestern began by a classmate talking to a friend; once initial entry was obtained, a particularly cooperative director ensured success. This researcher postulates that the best way to overcome the access issue and expand the data set is to network around the barrier with physical presence being essential; "cold" phone calls and email did not prove very fruitful. Other than the current professional literature, professional society websites containing recent conference presentations should be considered a potential valuable starting point. Those documents are in the public domain and may lead to productive discussions on the presented subject matter that, in turn, may lead to eventual access to research team personnel.

Further research should expand the sample set to include several TTOs (including the institutions involved in this investigation) to understand whether the type of “tension” between maximizing licensing income while maintaining the deepening relationship between faculty researchers and industrial firms (see above) exists for successful academic/industry research programs. That expanded sample set would serve to verify the reports of Mowery and Sampat and by Greenberg (see above) for non-traditional technology transfer programs.

The engineering clinic approach such as that practiced at the undergraduate level by the Chemical Engineering Department at Eastnorthern bears further investigation. Although engineering departments with similar approaches should be sought, the focus of this recommended follow-on research is not intended to simply expand this inquiry’s participant pool. Rather, it is recommended that the research be centered on the undergraduate multidiscipline teams working within a collaborative academic/industry relationship, as is the case at Eastnorthern. The purpose of the inquiry would be to determine the impact of this particular type of teaming environment on undergraduate engineering learning. Consideration should be given to a participant pool composed of the engineering colleges of several different research sites. For comparison purposes, some of the participating colleges would be chosen due to utilization of the subject teaming and industry-partnering concept while others use more traditional classroom methods. The utility of such an investigation is to provide an assessment of the impact of undergraduate multidiscipline teams that work with an industry partner on learning progress by comparing those students to similar students not engaged in similar teaming activity. In turn, that assessment could be used by other interested engineering colleges to evaluate potential curriculum modifications and/or involvement with an interested industry partner.

Of all the data gathered, analyzed and interpreted during this exploratory study, perhaps the single most surprising element was provided by the following quote from the Co-Director at the Southeastern ERC: "For most companies that support our research, recruiting is the major goal." The implication of the director's statement is that the recruitment of graduate students by industry is an objective that sometimes outweighs the importance of the results of the funded, collaborative research project itself. Further research into this stated concept is strongly recommended to test its validity. If considered true and perhaps even commonplace it has potential utility for academia: that the subject industrial recruiting practice could, in turn, be used as a recruiting tool to attract students to graduate engineering programs where the practice is actually in play. During the graduate program's recruiting process, the prospective students could be informed that certain companies fund projects at that college for the implicit purpose of evaluating future potential employees. Some of those prospects may consequently perceive the subject graduate program as holding better potential employment opportunities. The practice could serve as the determining factor for the graduate candidate when selecting one program over another where the subject type of recruitment is not known to occur; that may be especially true in today's difficult economic environment with high unemployment rates in certain regions of the US.

This inquiry established motivations for both academic and industry personnel engaged in collaborative team research that focused on environmental matters: education and income stream generation dominated, respectively. An unproven but suspected motivation for involvement by some of the research personnel (faculty, industry members or students) was doing research on the environment for the sake of improving some aspect of the environment. During the investigation faculty participants staunchly insisted that their primary motivation for project involvement was for the sake of their students. Participants from industry, either explicitly or implicitly, made it clear that their involvement was primarily motivated by revenue (or value) generation. Environment as a motivational factor for project engagement was not explicitly addressed by either survey or interview questions. It is recommended that the environment as principal motivator for this type of team research be investigated further. The utility of that knowledge would be that useful research projects might be established or existing projects could possibly be restructured to accommodate this motivation. As a result, those projects might be able to attract particularly capable personnel who could advance the overall goals of the project while adhering to their personal commitment to overarching environmental goals. The intent, of course, would be that such a team addition would complement, rather than disrupt, team members who are primarily focused on developing income streams or educating students. It is certainly possible that a project, which does generate revenue and educates students, could, with the addition of one very talented individual possessing a previously lacking skill set, be made more successful. Student educational experience may be enhanced and greater income generated while the personal goals of the environmentally motivated individual are achieved as well.

Closing

A 2002 editorial in The Economist, titled “Innovation’s golden goose,” describes passage of the Bayh-Dole Act as “Possibly the most inspired piece of legislation to be enacted in America over the past half century…” (The Economist, 2002, p. 3).

Using academic capitalism theory to describe the problematic flow of knowledge within the new economy, Slaughter and Rhoades offer: “Knowledge is construed as a private good, valued for creating streams of high-technology products that generate profit as they flow through global markets.” (Slaughter & Rhoades, 2004, p. 29). Those authors contrast this private good model to the public good model that Vannevar Bush introduced following the Second World War and academia, teamed with the USG mission agencies, successfully implemented and which clearly served the principles of academic freedom; discovery via basic academic research funded by the US government was the norm.

Clearly, a tension exists.

Public corporations are morally and legally obligated to attempt to provide value to their constituents. Educators are obligated to educate their students. Researchers seek scarce funds to support their efforts and fund graduate students. Federal and state governments reduce public university funding to divert resources to higher priority items. Corporations, seeking ways to generate profits, turn to the research capabilities of academia. Researchers, to fill funding gaps, accept the corporate funding to continue their research efforts and support their students. The price paid for that funding is denial of access to information since it has moved into the private domain to protect the competitive advantage of the corporate funding source. Bayh-Dole has certainly enabled this process.

The tension is over the principle of academic freedom. Some would argue that Bayh-Dole comes at too high a price: excessive harm to the public good due to the changes it has forced into the arena of academic research with the consequential diminution of academic freedom caused by impedance of the flow of basic scientific knowledge. This inquiry has clearly verified by example the existence of constraints on the flow of academic knowledge. Others would argue that Bayh-Dole has been beneficial to the nation due to the creation of products and processes it has enabled and those benefits are worth the price of significant changes in the academic domain, even at the cost of academic freedom. This inquiry has clearly verified by example the existence of public benefits realized by the process of technology transfer.

In closing, this researcher believes that university budget cuts imposed by government must be considered a reality that will persist and likely be exacerbated by the current economic recession. Further, the advantages of the technology transfer process demonstrated by the research projects of this inquiry are evident while their disadvantages are unquantifiable and fraught with uncertainty. Technology transfer, including the non-traditional type defined herein, can be used as simply another tool to overcome the reality of today's austere university budget environment. Bayh-Dole has served as an enabler of that approach. This study has also shown that non-traditional technology transfer can serve the betterment of the environment and provide value to industry while maintaining a mission-centered approach within the academy. If the diminution of academic freedom (i.e., as predicted by academic capitalism theory) is the price for those benefits, this researcher believes the price is worth the return.

APPENDIX A

NON-TRADITIONAL TECHNOLOGY TRANSFER SURVEY QUESTIONS

Thanks very much for taking the time to participate in this survey.

In this questionnaire, approximately 50 people will be asked to complete a survey that asks questions about technology transfer and the collaborative relationships between university and industry partners. It will take approximately 15 minutes to answer the questions.

Your participation in this study is completely voluntary. There are no foreseeable risks associated with this project. However, if you feel uncomfortable answering any questions, you can withdraw from the survey at any point. It is very important to understand your opinions; please use the comment boxes as you consider appropriate.

Your survey responses will be strictly confidential and data from this research will be utilized for only academic purposes. If you have questions at any time about the survey or the procedures, you may contact Paul J. Mallon by email at the address specified below.

Thanks again for your time and support.

Please start with the survey now by clicking on the **Continue** button below.

pjmallon@email.arizona.edu

1. What is your parent organization?
   - University
   - Industry
   - Other
2. Please provide title research project. (Leave blank if you wish to remain anonymous.)
3. What is your role on the research project? (Please choose all that apply.)
   - Principal Investigator
   - Co-principal Investigator
   - Industry participant
   - Graduate Student
   - Undergraduate Student
   - Technician
   - Other
4. Which participant initiated formation of the project team?
   - University
   - Industry
   - Other

5. What was the motivation for initiating your research project? (Choose all that apply. After making your selection(s), if you would like to comment please go to the "Please Explain" box immediately below.)

    - Scientific Discovery
    - Generate income for parent organization
    - Education

   Please Explain.

6. Do you expect your research efforts to serve the ecosystem? (After making your selection, please provide any comment you may have in the "Please Explain" box immediately below.)

    - (5) To a very great extent
    - (4)
    - (3)
    - (2)
    - (1) Not at all.

   Please Explain.

7. During the course of your project to what extent can engineering work be transferred from industry to participating engineering schools? (After making your selection, please provide any comment you may have in the "Please Explain" box immediately below.)

    - (5) To a very great extent
    - (4)

- (3)
- (2)
- (1) Not at all

Please explain.

8. To what extent is your research project being conducted to improve the overall ecoefficiency of the participating firm(s)? (After making your selection, please provide any comment you may have in the "Please Explain" box immediately below.)

   - (5) To a very great extent
   - (4)
   - (3)
   - (2)
   - (1) Not at all.

   Please Explain.

9. To what extent is the dominant motivation for executing your research project to generate new income streams for the participants? (After making your selection, please provide any comment you may have in the "Please Explain" box immediately below.)

   - (5) To a very great extent
   - (4)
   - (3)
   - (2)

- (1) Not at all.

Please Explain.

10. To what extent is society being served by your research effort? (After making your selection, please provide any comment you may have in the "Please Explain" box immediately below.)

    - To a very great extent
    - (4)
    - (3)
    - (2)
    - (1) Not at all

    Please explain.

11. To what extent is your research project being conducted to meet government environmental regulations? (After making your selection, please provide any comment you may have in the "Please Explain" box immediately below.)

    - To a very great extent
    - (4)
    - (3)
    - (2)
    - (1) Not at all

    Please explain.

12. To what extent are the principles of "green" engineering being adhered to during the execution of your research project? (After making your selection, please provide any comment you may have in the "Please Explain" box immediately below.)

- To a very great extent
- (4)
- (3)
- (2)
- (1) Not at all

Please explain.

13: Is it the intention of the industry participant to have its university counterpart perform work that it otherwise could not do?

- Yes
- No

If “Yes”, branches to -> 14.

If “No”, branches to -> 15.

14. To what extent can engineering work be transferred from industry to participating engineering schools? (After making your selection, please provide any comment you may have in the "Please Explain" box immediately below.)

- To a very great extent
- (4)
- (3)

- (2)
- (1) Not at all

Please explain.

15. To what extent does the success of the project's engineering work rely on the experience level of the university research staff? (After making your selection, please provide any comment you may have in the "Please Explain" box immediately below.)

- To a very great extent
- (4)
- (3)
- (2)
- (1) Not at all

Please explain.

16. To what extent can the research project serve the education goals of the university participant? (After making your selection, please provide any comment you may have in the "Please Explain" box immediately below.)

- To a very great extent
- (4)
- (3)
- (2)
- (1) Not at all

Please explain.

17. To what extent is the industry partner using the research effort as an employee recruiting tool? (After making your selection, please provide any comment you may have in the "Please Explain" box immediately below.)

- To a very great extent
- (4)
- (3)
- (2)
- (1) Not at all

Please explain.

APPENDIX B

NON-TRADITIONAL TECHNOLOGY TRANSFER INTERVIEW QUESTIONS

1. To what extent do you believe your project (*give project title*) to be collaborative with members of industry (*or academia*, depending on the interviewee)?
2. If you had to define a technology transfer project, how would you do this? (Where would you start to define it?)
3. Given your previous reflections, in your opinion, do you consider your project (*give project title*) an example of technology transfer?
4. Could you tell me how did your organization (*name the university/ERC/company*) first get involved in this project (*name the university/ERC/company*) ?
   a. Why did you initially go to the organization (*name the university /ERC/ company*)?
   b. Did you need help from the organization (*name the university /ERC*) to achieve your project's goals?
   c. Before you went to the organization (*name the university /ERC*) did you explore other options to accomplish your project's objectives?
   d. To what extent do you consider this effort a transfer of work from your firm to the university?
5. Could you please expand on the ways your research project has to do with the ecoefficiency of the participating firm and comply with government regulations?
   a. Would you say it has improved? or not? or to what extend?

b. Similarly, do you consider this collaborative project a new source of income?

6. In your opinion, do you consider there are ways your project (*give project title*), to be helpful for the environment? could you describe them to me?
7. How would you relate your project (*give project title*) to the principles of Green Engineering? Are there ways to connect them or would you say something else?
8. To what extent do you consider the project work accomplished by the university personnel to have helped your company?
9. To what extent do you consider the project work accomplished by the university personnel to have served as a recruiting tool for your company?

APPENDIX C

DISSERTATION PARTICIPANTS

Institution	Organizational Component	Corporate Partner(s)
Southwestern University (SWU)	Engineering Research Center (ERC) For Product and Process Xray	IndiaOne IndiaTwo
Southwestern University (SWU)	Astronomy Department	Romeo Mike (CRM) Startup Tango
Eastnorthern University (ENU)	Chemical Engineering Department	Mike (CM)
Southeastern University (SEU)	Engineering Research Center (ERC) For Product and Process Yankee	Startup Victor IndiaOne IndiaTwo Echo Foxtrot Golf

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