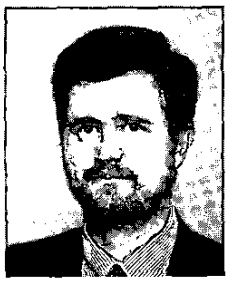

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Introduction by JMJ

This month's PACE Report consists of another excellent article about teaching entrepreneurship to engineering students. Specifically, in this article the authors provide details of a program at the University of Michigan that attempts to foster and stimulate entrepreneurial activity among student researchers. Among other things, a process of commercializing academic research and its relationship to fostering entrepreneurial activity at the university is detailed. The article is reprinted with permission from the *Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition*. The article is copyrighted 2003 by the American Society for Engineering Education.

Academic and Professional Resources for Student-Led Technology Ventures

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Abstract

Student researchers face daunting challenges when attempting to take a developed technology and use it as the foundation for an emerging enterprise. Engineering students typically lack an overall understanding of the commercialization process associated with academic research. Moreover, the resources required by the student span several disciplines including law, business, and engineering. Only recently have engineering programs included entrepreneurial courses covering the basic concepts that are essential for technology-business development. At the University of Michigan, such courses include an MBA business-plan development sequence that an increasing number of engineering graduate students elect, an undergraduate engineering course in business-plan development, and a patent-law class specifically for engineering students. Academic resources such as these significantly increase the likelihood of stimulating student entrepreneurial activity as well as successful commercialization of university research. However, these resources alone are typically insufficient. Professional resources, such as those offered by the Technology Management Office and the Zell-Lurie Entrepreneurial Institute at

Michigan, provide business development support, ranging from one-on-one business development counseling to grant programs for emerging business from university research. In this paper, we discuss the complete process of commercializing academic research. We address critical academic and professional resources in the process of business development and how they have fostered entrepreneurial activity, which has contributed to successful commercialization of engineering research at the University of Michigan. Several of the challenges faced by the student entrepreneur have been addressed by these resources at Michigan, while others still require further development that is well underway. Here we report on these activities, while aspiring to foster inspiration for the development of entrepreneurial resources at engineering institutions across the country.

1. Commercialization of Engineering Technology

1.1 An Engineering Student Researcher's Perspective

Graduate-student researchers are all too often completely isolated from any notion of commercializing their research. As such, it often appears as a daunting challenge to the student. The irony of the circumstance is that a great deal of engineering research has tremendous commercial potential. Moreover, engineering students are quite prone to developing an interest in emerging business, given the success of a breadth of technology startups in the past decade. However, once that interest has come to fruition, where does the student go from there? Many engineering students and researchers forgo their entrepreneurial ambitions simply from a lack of knowledge and resources. Of course, this comes as little surprise, since the questions faced can seem overwhelming. Intellectual property (IP) is almost a completely foreign concept to most student researchers. In previous years, the idea that one can utilize university resources to commercialize technology has been received with utter surprise by many student researchers at Michigan. But even with these resources, students begin to ask themselves, how can a business plan be developed? How can one learn about business development while pursuing an engineering degree? How can capital be raised to support an emerging business? Who can help? And quite simply, where should one start? It is our contention that an engineering curriculum in the US should support students along this career path by providing resources, both academic and professional, such that these questions are answered and students can pursue their career ambitions with the appropriate knowledge.

1.2 The Importance

There exist strong advocates both for and against commercializing university research. Arguments for each are intelligent and significant. Opponents voice concerns regarding conflicts of interest, ethics, and compromising situations surrounding ambiguity in defining one's primary appointment: Is it at the university or within the company? These concerns are clearly legitimate, but they can be addressed with proper conflict management. Proponents have recognized the current trend that both domestic and foreign corporations are relying more heavily on external technology and intellectual property to feed their commercial pipeline. Specifically, early stage research and development is often no longer corporately captive, and thus companies are now creating and integrating new intellectual-property supply chains into their business models. Colleges of engineering across the country are well-positioned to play an active role in this chain. Figure 1 illustrates the percentage of companies relying on external sources for technology in North America, Europe, and Japan. The trend for the past nine years clearly indicates that the livelihood of the global technology economy is dependent on these external resources. Therefore, it is of utmost importance that educators in colleges of engineering recognize the need to develop resources that prepare their students to make such necessary and in-demand contributions.

Of equal significance are the opportunities that exist in emerging business. In recent years, the infusion of capital into venture funds has been nearly exponential, as shown in Figure 2. The market experienced a substantial downturn in 2001, but the shear magnitude of investment dollars is still staggering. This trend also reflects the fact that much early stage research and commercialization is occurring through emerging business, and not within large corporate entities. These trends have created career opportunities for US engineers that are substantially different from previous years. However, education will be the key that distinguishes these engineers in the competitive marketplace. Only the properly educated engineer will be able to succeed in building an emerging business from the ground up.

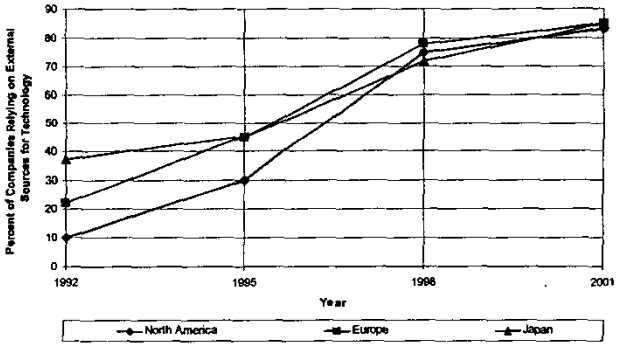

Figure 1. The percentage of companies relying on external sources for technology from 1992 to 2001 [1].

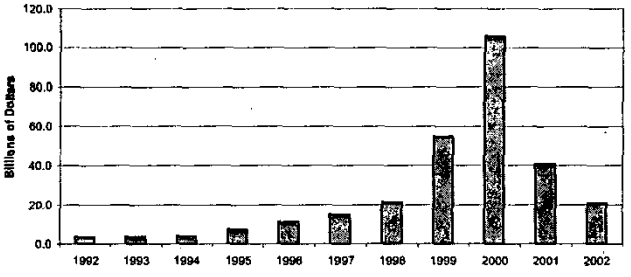

Figure 2. US venture capital investment from 1992 to 2002 [2].

1.3 Commercialization at the University of Michigan

Many colleges of engineering are at various stages of development in terms of technology commercialization and transfer. In fact, some have gained a certain amount of notoriety for the lack of an efficient technology management system. The University of Illinois is one such example, but in 2002, under new leadership, the university revamped its system substantially, and took a good look at peer institutions such as Michigan and Wisconsin. Now the institution is taking great strides in the process of technology commercialization [3]. Clearly, other institutions can follow suit.

In the text that follows, we examine in detail the commercialization process that is implemented at the University of Michigan, so as to develop an understanding of this process for both faculty and students, as well as technology managers. Figure 3 captures the described milestones that follow.

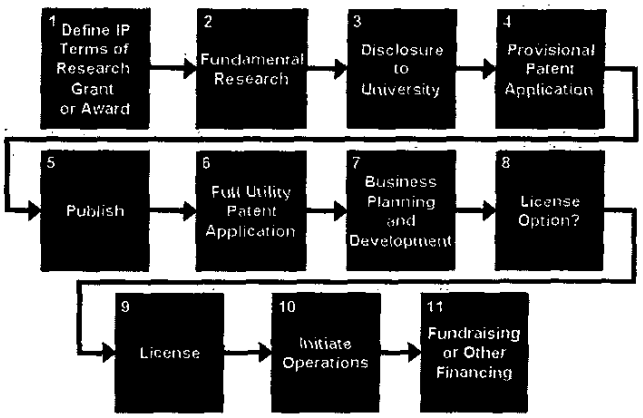

Figure 3. Commercialization Milestones: A summary of the process of technology transfer to emerging businesses at the University of Michigan. Milestone numbers are referenced throughout the text.

1. Define IP Terms of Research Grant or Award: It is imperative that the intellectual property assignment be clean for any contracts, grant, or gift monies received. This enables the university to later license the developed technology into an emerging enterprise. The Bayh-Dole Act of 1980 was substantial legislation that essentially transferred ownership of IP from granting federal agencies to the awarded institutions [3, 4]. Thus, federal grants are typically clear from any commercial obligations, and the developed intellectual property can be licensed from the university at which the research was conducted. Complications typically occur when collaboration exists with commercial entities. Often, these companies wish to retain some or all rights to the intellectual property developed with their funding, which is reflected in the research contract, thus limiting the choice of commercialization paths. Negotiations with external entities prior to acceptance of any research award is mandatory to eliminate this pitfall. It should be noted that inventorship is separate from partnership and licensing; thus, inventors will still be listed on all patents, regardless of how they are utilized for commercialization.

2. Fundamental Research: During this period, the researchers develop the initial technology and any IP surrounding it. It is imperative that researchers understand that developed concepts cannot be disclosed to outside parties at this time. This includes Web pages, conference and journal publications, and a variety of other forms of media. If the technology is disclosed, a one-year time limit is imposed from the date of disclosure to the application deadline for a US patent. Additionally, all foreign filing opportunities are lost.

3. Disclosure to University: The University of Michigan utilizes an internal disclosure process. Typically, researchers will file a pending publication as full disclosure of the technology. However, a variety of formats are acceptable.

4. Provisional Patent Application: The Technology Management Office will review the submitted disclosure and, under advice of a committee, determine whether the technology is worthy of development into intellectual property. If so, a provisional patent application is filed. The provisional application is inexpensive, simple, and timely. It offers the inventors the ability to publish research while the technology is protected for one year. Within that year, a non-provisional, or full utility, application must be filed. The grace period is often an advantage, since inventors have time to further refine the intellectual property. Also, development of a full utility application is costly and time consuming. The provisional application quickly puts a time stamp on the technology. The Technology Management Office at the University of Michigan assigns the case to a patent attorney, who then files this application.

5. Publish: Once the provisional patent application is filed, the researchers may choose to publish their work in the typical forums.

6. Non-provisional Patent Application: Within one year of the provisional filing, a non-provisional application must be filed. This application is extensive and time consuming. The inventors are much more involved in this process, and typically work directly with the patent attorney throughout the development of the application. The Technology Management Office facilitates this interaction.

7. Business Planning and Development: Once the IP is established, the researchers can now develop a business plan. Here it is critical to leverage resources for varying departments and units within the university. Typically, a core founding team is established at this point, and it is often comprised of a mix of technologists and business personnel. Then, legal counsel is retained and a corporate entity is established. In subsequent sections of this paper, we will discuss resources that Michigan has developed to foster emerging business development, as well as team formation.

8. License Option: The researchers may choose to engage in a license option for the developed IP. At Michigan, this typically involves some set of negotiable terms under which the technology is removed from the open market while the researchers examine its commercial potential. Often the university requires some type of business plan or development timeline in order to grant a license option. The option agreement often involves a fee paid by the licensee. In return, the licensee can examine the technology exclusively, and later exercise the option to license the IP outright. Moreover, the fee is substantially less than that required for a full license.

9. License: Once the researchers have built a complete business plan that they intend to execute, it is reviewed by the

Technology Management Office. Here an outright license is negotiated and a variety of terms are established, including the equity and royalty structure that is paid to the University, milestones, and fees. Once the license is executed, the researchers can now move out of the University with the technology and sell products based on it.

10. Rollout: Sell or Continue Development: Here the researchers typically continue some development of the technology in order to refine it for commercial applications. Once complete, they are ready to begin marketing the product. At this point, funding may be sought in order to complete commercial development.

11. Fundraising or Other Financing: Possessing IP is a critical milestone for any emerging enterprise. Fundraising and financing become substantially easier when the IP position of a company is locked down. From this point, the researchers retain the rights to commercialize the developed IP and they have brought the technology to some nearly commercial status. Fundraising is often performed in collaboration with Technology Management Office and other professional resources.

This discussion clearly indicates the breadth of activities required for commercialization of engineering technology – the most notable include resources for intellectual-property development, business-plan development, interaction with fellow entrepreneurs, and fundraising support. In the sections that follow, we describe resources that have been developed recently at the University of Michigan in order to address many of these challenges.

2. Academic Resources

In recent years, Michigan has established a variety of entrepreneurial courses for both its undergraduate and graduate engineering students. Some are offered in the college of engineering, while others are electives that an increasing number of engineering students select as part of their curriculum. These courses are described in the sections that follow.

2.1 Courses for Engineers [5]

Electrical Engineering and Computer Science 498: Patent Fundamentals for Engineers. This course covers the fundamentals of patents or intellectual property, and is geared for undergraduate and graduate students in engineering. The first part of the course focuses on the rules and codes that govern patent prosecution in the US. For example, we cover, in summary, most parts of the *Manual of Patent Examining Procedure* (MPEP), with a special emphasis on examination of patents and patentability of applications. The second part of the course focuses on the strategies and methodology for claim drafting and patent prosecution. Since it is important to write a patent with the opponent in mind, some lectures also examine litigation issues and common techniques used to overturn patents. Finally, the ethics, codes, and licensing agreements are covered briefly. As a final project, the students have an opportunity to write their own patent on an invention of their choosing, which includes the specification, drawings, and claims. The best applications may even be filed in the US Patent and Trademark Office.

Industrial and Operations Engineering 422: Entrepreneurship: Engineering students will learn the dynamics of turning an innovative idea into a successful commercial venture, including the role of e-commerce. By creating an actual business plan, they will learn about innovation and creativity, risk management, stress and failure, ethics, and other necessary business skills.

These courses are easily accessible to engineering students, as they are offered within the College of Engineering. They offer the student knowledge in two critical areas of emerging business: intellectual property and business-plan development with a team. These courses are primarily undergraduate courses, although many graduate students elect the intellectual-property course, as it is most pertinent to their research and the development of IP surrounding it.

2.2 Business Electives [6]

Entrepreneurial Studies 515: New Venture Creation I. To be successful, entrepreneurial ventures require something new, something better, which can provide a competitive advantage. This new and better product, market, or process is termed the venture concept. The ES515 course first looks at the other factors that lead to entrepreneurial success – the characteristics of the entrepreneur, the trends in the environment, and the availability of support – and then focuses on the means of developing innovative products, markets, or methods that can serve as viable venture concepts. Lastly, the course considers the means of defining those concepts so that they are clearly understandable to other people, and of confirming the competitive advantage or advantages so that they are clearly recognizable by potential investors. Defining the concepts and confirming the advantages are essential before large amounts of time are invested in the preparation of a complete business plan.

Entrepreneurial Studies 517: Researching & Writing the Business Plan. Once new and better products, markets, or processes have been defined and confirmed for a new entrepreneurial venture, whether a startup or turn-around, it is necessary to prepare a full business plan. A full business plan is more than just a document that is to be handed to potential investors; it is a detailed road map of the actions that will have to be taken to either start or turn around the proposed new venture. As such, it should contain sections on marketing policies, market research, production policies, cost analysis, organizational policies, financial projections, financial sources, and long-term growth plans. The ES517 course looks at each of these sections in detail, and helps students in the preparation of realistic business plans based upon their startup or turnaround venture concepts. Teams of four or more students complete business plans for venture concepts defined and researched in ES515.

These courses are part of the MBA curriculum and are taken as a sequence. Nevertheless, several engineering graduate students elect these courses as part of their curriculum. Students may present business concepts to the class, and those that generate the most interest are assigned a team. Enrollment is not necessary to present a concept, and thus some engineering students simply present technology business concepts to the class and recruit a team to develop a plan. These courses offer student researchers essentially pro-bono business-plan development from relatively skilled students within the MBA program. At a minimum, the result is a

baseline business plan that the student researcher can refine at a later date.

2.3 Resources Offered by Student Organizations

Several student organizations have become instrumental in not only pooling resources across the university, but also breaking down the barriers that exist between departments as well as colleges. A grassroots organization, appropriately named Michigan Entrepreneurs, was founded by electrical engineering students in 1999, and has established itself as the furthest-reaching organization addressing student-led emerging business. A description and mission of the organization follows:

> Michigan Entrepreneurs (UME) is an association of students devoted to exploring the many opportunities that surround us all in today's exciting business world. Our mission is to create a community of students interested in exploring these opportunities through education, meetings, influential speakers, and workshops. UME is a unique campus group as it is open to the entire community. You'll find engineering, music, literature science and arts, and business students in this diverse and exciting organization [7].

UME has sponsored events including a showcase of entrepreneurial startups by Michigan students. Here, students of all disciplines are able to learn of the experiences of colleagues in the development of their business. UME has also developed focus groups on particular aspects of technology and business, from semiconductor technologies to patent law. However, what the organization does more than anything is foster interaction among students, faculty, and the local business community. The organization has created a truly transparent network, where individuals of all disciplines can interact. This interdisciplinary interaction has been instrumental for many in recruiting a team to develop a business concept.

Other organizations at Michigan have been formed by business students, but they often collaborate with the College of Engineering for certain events. These organizations include the Entrepreneur and Venture Capital Club, as well as the High-Tech Club. Both clubs also participate in circulating solicitations to their members from engineering teams looking for business talent.

3. Professional Resources

Student organizations and course work can take an engineering student a long way, but the professional resources available to Michigan entrepreneurs are what truly allow engineers to develop the skill set required to become a successful entrepreneur. Here we discuss two significant organizations and their role in commercializing engineering research: the College of Engineering Technology Management Office and the Zell-Lurie Entrepreneurial Institute.

3.1 The College of Engineering Technology Management Office

The vision of the College of Engineering (CoE) Technology Management Office is as follows:

> The goal of the College's Technology Transfer & Commercialization function is to expand the impact of CoE research through commercialization and to effectively transfer University technologies to the market so as to generate benefits for the University, the community, and the general public. The office provides assistance with Michigan's technology transfer process, disclosures, patents, copyrights, licensing, and proposals [8].

The Office does just this, and does it well. With a clear technology-transfer process and support for any student researcher wishing to commercialize developed technology, this Office is indispensable. The Office also provides valuable support, including assignment of a business-development specialist to each individual or group aspiring to commercialize engineering research. The specialist will introduce the researchers to the technology-transfer process at the University, arrange appointments with potential investors, clarify the group's IP position to investors, and support the group in its business-development efforts. These professional resources provide engineering student researchers with additional information that is unlikely to be found in the classroom.

The Office also provides significant monetary support for researchers aspiring to develop a new business. The Engineering Technology Development GAP Fund is a fund targeted at providing monetary support in order to bridge the gap between research prototypes and commercially viable products. The Office also uses discretionary money to support consultants in business development. The idea is to foster interaction among researchers and seasoned entrepreneurs from the community. These opportunities greatly facilitate the development of a core business team.

3.2 The Zell-Lurie Entrepreneurial Institute

The Zell-Lurie Institute is affiliated with the University's Business School. Founded in 1999 with a ten-million-dollar gift from Samuel Zell and Ann Lurie, the Institute has moved forward with the following mission:

> The Institute is as an umbrella for existing and expanding efforts in entrepreneurship. Approximately sixteen faculty members, both academics and practitioners in the field of entrepreneurship, prepare students for turning knowledge into new venture success. In addition, the Institute offers symposia, internships, scholarships, alumni networks, curriculum development, and other activities to advance the interests of the entrepreneurial community [6].

The Institute has been instrumental in linking engineering-student researchers with MBA students. Its members participate actively in the MBA business-planning courses, and collaborate with engineers aspiring to develop business plans in these courses. Most importantly, though, the Institute facilitates access to MBA students.

The Institute also administers its own grant program, the Dare to Dream Program, where teams may present business proposals in collaboration with Michigan MBA students and receive funding for commercialization efforts. In addition, the Institute manages a program that subsidizes internship salaries for Michigan MBA students at startup companies in the area. Companies that

utilize this resource receive world-class talent at half the price, and several companies have found this to be a cost-effective manner in which to retain desired talent, with salary, despite low cash flow.

Lastly, the Institute provides teams with access and sponsorship to business-plan competitions around the country. Faculty and staff at the Institute will coach teams prior and during their attendance at these events. It has been an invigorating experience for many students to present their business concepts in a competitive format, while interacting with fellow student researchers and entrepreneurs across the country. The Business School also manages business-plan competitions of its own, and participation has been increasing steadily over the years.

The availability of these resources to engineering students, despite the fact that the Institute is housed by the Business School, is an outstanding facet of the entrepreneurial culture at Michigan. The boundaries that exist across academic disciplines, such as business and engineering, must absolutely be broken down in order to foster a healthy entrepreneurial community and develop the resources required for students.

3.3 Connections to External Resources

Both of the offices described previously play an instrumental role in connecting entrepreneurs with external resources and, in particular, to venture capital, grant programs, legal support, and professionals within the community. This final aspect of the environment at Michigan is the most significant. Entrepreneurs require some form of communication with those outside of the university environment. They must get some feel for what it is like to raise money through grants or venture capital. Interaction with entrepreneurs in the community is a critical component to developing the entrepreneurs of tomorrow. Both the Zell-Lurie Institute and the Technology Management Office sponsor events that connect student and faculty researchers with business students and faculty as well as members of the outside community.

4. Statistics Measuring Entrepreneurial Activity at Michigan

The College of Engineering Technology Management Office provides valuable statistics that indicate the level of activity of technology transfer at the University and within the College [9]. We present these statistics here as a measure of success of the various resources presented previously.

Figure 4 is a breakdown of the disclosures made to the Office in fiscal year 2002 and divided by engineering discipline. Not surprisingly, the two largest departments – electrical engineering and computer science, and mechanical engineering – comprise the bulk of the activity. These statistics also indicate areas in which entrepreneurial programs can be strengthened.

The best indication of increased commercialization activity is given by the dramatic increase in disclosures and patented technology in the College of Engineering. Figure 5 illustrates the trends for six years. In 2002, the College generated almost twice as many disclosures as it did in 1997. The numbers of patented technologies actually tripled from 1997 to 2002, indicating that not only had the quantity of disclosures increased, but also the quality and commercial viability of those disclosed technologies. Licensed

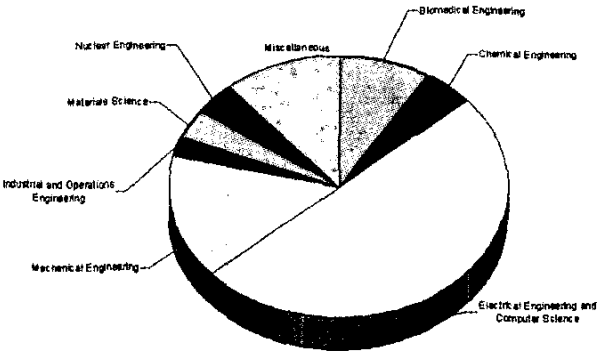

Figure 4. A breakdown of disclosures in FY2002 at the University of Michigan by engineering discipline.

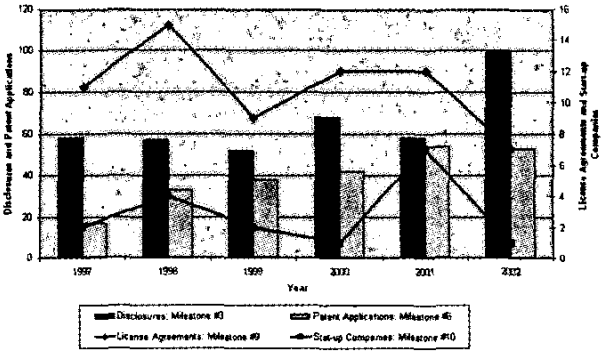

Figure 5. University of Michigan College of Engineering disclosures, patent applications, license agreements, and startup companies from 1997 to 2002.

technologies have ebbed and flowed for the past five years and the general trends follow the availability of venture capital, which can be correlated with the health of the national economy.

The true and final metric indicating increased entrepreneurial activity is the number of start-ups that have originated from the College. Figure 5 illustrates these data for six fiscal years. Although a sharp decline was experienced in 2000, the general trend is increasing, and an unprecedented number of engineering start-ups was recorded in 2001, totaling seven.

5. Conclusion

In this paper we have presented the importance of educating engineering students in the area of commercializing engineering research and technology in today's economy. The process for commercializing research at the University of Michigan was described, in order to create an appreciation for the breadth of activities involved. Both academic and professional resources have been developed at the University of Michigan and were described in detail. Clearly, course work is an important starting point, in order to foster the interest of engineering students and provide the support required for business-plan development and IP protection. However, the significance of professional resources cannot be overlooked. As described, many of the resources required by an entrepreneur are not academic in nature. If a student researcher

aspires to commercialize his or her developed technology, then a team must be built, relationships must be established, and financing must be secured. These are the less-tangible resources that will make or break the entrepreneurial environment at an engineering research institution. The culture, community, and resources at Michigan have come a long way in a short period of time, and we have reported statistics that indicate a substantial increase in entrepreneurial activity. Nevertheless, courses continue to be added to the curriculum and programs continue to develop to fulfill the needs of aspiring engineering entrepreneurs. In closing, we hope to have contributed to the spirit of enterprise and the development of engineering technology through research, while inspiring others in the development of their own entrepreneurial resources for students.

6. Acknowledgement

We wish to thank Dr. Timothy Faley and Karen Studer-Rabeler of the University of Michigan Technology Management Office for valuable data included in this paper. Further thanks go to the University of Michigan Zell-Lurie Institute and, in particular, to Paul Kirsch, for thoughtful comments and insight regarding the development of this paper.

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Introducing the Authors

Michael S. McCorquodale received the BSE degree with honors in Electrical Engineering from the University of Illinois at Urbana-Champaign in 1997, and the MSE and PhD degrees in Electrical Engineering from the University of Michigan in 2000 and 2004, respectively. While at Michigan, Michael was awarded the Harry Benford Award for Entrepreneurial Leadership and the Distinguished Achievement Award in Electrical Engineering, both for his efforts surrounding the development of emerging technology business at Michigan. Currently, Michael is the Chief Executive and Technology Officer of Mobius Microsystems Inc., a startup formed around his graduate research in high-accuracy and low-jitter monolithic clocking for embedded microprocessors, which was conducted under the direction of Prof. Richard B. Brown. Mobius has received a wide variety of recognition throughout its growth, including first place awards from six national and international business-development competitions. Mobius received an equity round of financing in 2004, and is currently engaged in several customer projects.

Richard B. Brown received BS (with Highest Honors) and MS degrees in Electrical Engineering from Brigham Young University in 1976. From 1976 to 1981, he worked in computer design as Vice-President of Engineering at Holman Industries, Oakdale, CA, and then as Manager of Computer Development at Cardinal Industries, Webb City, MO. He returned to school at the University of Utah in 1981, and received an electrical engineering PhD in 1985. In September, 1985, he joined the faculty of the University of Michigan Department of Electrical Engineering and Computer Science (EECS). Prof. Brown has conducted major research projects in the areas of solid-state chemical sensors, high-performance microprocessors, and low-power systems-on-chips. He is the micro-power electronics task leader in the University of Michigan NSF Wireless Integrated Microsystems Engineering Research Center. He has won a variety of teaching and research awards, and served as Associate Editor and guest Editor of several journals, and as Chair, Program Chair or Executive Committee member for a number of conferences. While at Michigan, Prof. Brown developed the integrated circuit design (VLSI) program. He served as Associate Chair for the Electrical Engineering Division of EECS for four years, and then as Interim Chair of EECS from July, 2001, through May, 2003. He enjoyed a sabbatical at the IBM Austin Research Lab, and then became Dean of Engineering at the University of Utah in July, 2004.