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Early Stage Technology Development and Commercialization: An Investment in Innovation That Yields an Economic and Educational Impact

Abstract

This paper describes efforts to incorporate engineering students into early stage technology development and commercialization projects for industrial clients. In this model, students are mentored in a professional experience much like medical students are mentored in professional practice in teaching hospitals. This service is provided by the Advanced Manufacturing Institute (AMI) at Kansas State University. Entrepreneurs and businesses utilize these services to carry their inventions across the ‘Valley of Death.’

AMI has invested grants from the National Science Foundation, the U.S. Economic Development Administration, and the Kansas Technology Enterprise Corporation to build an organization dedicated to commercializing technologies by adapting the teaching hospital concept of mentored professional development. Since 1995, AMI has mentored more than 380 students and completed more than 2,500 projects for more than 450 businesses and entrepreneurs. A partial survey of our clients indicates we have helped create more than 500 jobs, influenced the retention of more than 300 jobs, increased product sales by more than $100M and reduced costs by $10M.

In this paper, we share three key aspects of this unique program. First, we will share our model for employing industrially experienced professionals to mentor students to accomplish early stage technology development and commercialization projects at Kansas State University. Second, we will share summaries of example projects we have completed including an invention that was recognized as one of the nation’s best in 2005 and a product that is being sold across the nation. Finally, we will reveal ways that K-State is realizing an economic benefit from these activities that goes beyond licensing intellectual properties and includes the production and sales of products.

The program described in this paper enhances the education of university students while simultaneously deriving economic benefits for both university programs and private enterprise. This model increases the readiness of graduates for professional work, increases the likelihood of financial returns to the university, transforms university intellectual property into market-ready products, and provides a resource to entrepreneurs and small businesses to improve their competitiveness.

1. Background

The Advanced Manufacturing Institute (AMI) is a multi-disciplinary center that is part of the Kansas State University College of Engineering. It is both a Kansas Technology Enterprise Corporation (KTEC) Center of Excellence and a U.S. Economic Development Administration University Center. Its mission is to advance technologies, people, and companies through collaborative engineering and business partnerships.
In 1995, AMI established an operation to enhance the education of engineering students that was patterned after teaching hospitals. In our model, AMI employs students to work on significant engineering projects for paying clients under the supervision of an experienced engineer. The start-up of this operation was partially funded by NSF grants. In this operation, AMI employs experienced engineers and other professionals to mentor students to conduct engineering projects for industrial clients. Since its inception, AMI has completed more than 2,500 projects for more than 450 entrepreneurs and companies.

In the beginning, projects were simple, low-cost, and relatively small. Successful projects led to repeat clients with larger and more challenging projects. Current projects include product and machine design, commercialization, engineering analysis, testing, accelerated design verification, and process engineering. Clients include entrepreneurs and existing businesses from across the United States.

AMI leaders began to recognize that some of the engineering projects being completed were technically successful but did not result in a significant economic impact. Furthermore, AMI was not creating a significant number of products from inventions created by university researchers. To address these issues directly, AMI decided it must get more involved with its clients to determine not only if the project could be done, but if it should be done.

To do so would require a significant expansion of our staff and an investment in infrastructure. At the minimum, we felt that we needed to recruit a commercialization project manager and an industrial product designer. We expected that these new professionals would mentor students in keeping with our mission and model. Furthermore, these individuals were expected to create enough funding from their projects to make their efforts affordable to AMI.

In 2004, AMI was awarded a University Center grant from the U.S. Economic Development Administration in 2004 that enabled us to expand our engineering work into providing commercialization and early stage technology development (ESTD) services. In addition, AMI was awarded an NSF Partnerships for Innovation grant in 2004 that specifically supports the expansion of AMI programs to accelerate the commercialization of bioscience-based products and technologies. In this paper, we use the U.S. Department of Commerce definition of ESTD, “to describe the technical and business activities required to develop a nascent technology into a clearly defined product or service whose specifications and business plan are matched to a particular market. ESTD and invention-to-innovation transition are equivalent in our usage.”

AMI’s goal was to establish an ESTD Assistance Center that would help entrepreneurs and existing businesses to develop and commercialize new products and technologies. These activities have now been conducted for more than two years and are fueling an expansion in AMI. Today, our operation has grown to the point of employing twenty-two full-time employees and forty students. Our group includes two commercialization project managers, one industrial product designer, and thirteen industrially experienced engineers: three industrial engineers, six mechanical engineers, one agricultural engineer, one electrical engineer, and two chemical engineers.
2. Purpose of K-State’s Early Stage Technology Development Assistance Center

The specific objectives for our ESTD Assistance Center are: to increase the number of technology-based products brought to market, with special emphasis on projects that have a positive economic benefit in Kansas; and to significantly involve students in these projects. To do so, our ESTD Assistance Center helps entrepreneurs and existing businesses to bridge the ‘Valley Of Death’ and increase the survivability of new product ventures. Clients are expected to pay the cost of this activity. Students are paid to work on projects under the supervision of experienced professionals. There are deadlines and budgets, real people with real dreams, and lots of business and technical unknowns and challenges. This activity involves business and engineering students in these processes. In addition to being paid for their work, students receive a mentored professional experience that significantly enhances their education in a way that helps them appreciate the business and technical challenges associated with developing and commercializing a new product. This experience opens the student’s eyes to entrepreneurial endeavors and prepares them to become better engineers and entrepreneurs and/or prepares them to work with entrepreneurs and to become effective members on ESTD project teams.

The goals for the K-State ESTD Assistance Center are:
- Reduce the probability of new product failures through the proactive and integrated management of technical and market risk
- Close the commercialization gaps (financial, technical, information, and trust) between scientific breakthroughs and market-ready products
- Accelerate the development of future engineers and technology entrepreneurs
- Facilitate technology based economic development in rural Kansas communities by making technology expertise accessible to rural companies
- Maximize the investment of AMI resources for greatest economic impact and financial return

3. ESTD Assistance Center Clients

To accomplish the goals of our ESTD Assistance Center, AMI provides commercialization and ESTD services to develop and bring new products to market. Clients include entrepreneurs and existing businesses. They are expected to pay for the services they require. Most of these clients have been either previous AMI clients, referred to AMI by past clients, or referred to AMI from economic development agents. To date, very few of our projects have originated in the university.

Though we have been able to generate more interest from clients outside the university than we can handle, we have struggled to develop significant interest in our services within the university to exploit the commercialization capability that we have developed. We envision, and are working toward, the creation of a pull-oriented process for developing and hardening university technologies and entrepreneurial product ideas. Unfortunately, K-State is similar to many universities who typically focus their commercialization efforts on filing for patents and then licensing the technology to others in hope of generating an income stream to the university and its inventors.
It is difficult to describe the clients that use our services. Some come to AMI with just a concept. Others have a working prototype. Some have an existing product in the market and want to increase sales while others think they should become rich just because they had an idea for a product. Some have already protected their intellectual property (IP) while others would violate existing IP if they bring their product to market. Others have paid to patent something that has little market value or which does not protect their IP sufficiently.

4. Project Execution

Regardless of who the client is or what services they need, AMI begins each project by analyzing both the client and the project opportunity to determine whether the project fits with our organization and what the potential benefits might be for conducting the project. To do so effectively, AMI has primarily invested its project acceptance decision process in a small team of individuals who review each project opportunity. We are currently in the process of developing a filtering process that could be deployed more broadly and uniformly throughout the organization.

Once a project is accepted, a contract is drawn up that defines project deliverables, timeframe, and cost. A project manager is assigned to the project and a team is assembled based upon project needs. The team composition can change over time based on project needs. Project contracts specify payment, deliverables, and deadlines. The project contract also spells out the handling of project IP – both IP brought to the project by the client and IP developed by the project. Projects are typically broken into small segments so that the client can change directions efficiently or limit their potential financial investment in the work based on results provided. To help entrepreneurs and small businesses in rural communities afford the ESTD and commercialization services that AMI provides, AMI developed an Industry Matching Funds & Funding Assistance Program. This fund was established by our EDA University Center grant.

To execute the project, AMI follows a stage-gate process. We have licensed stage-gate from the Product Development Institute and have been customizing the process for our use. This includes the ability to disseminate project information across the AMI intranet. Our objective is to increase the probability of success or to fail fast. Consequently, AMI is conducting more projects with a hands-on, rough and rapid prototyping mentality. This process is meant to quickly model a variety of ideas and test them quickly (fail fast) rather than simply choosing the “best” alternative and beating it into submission.

5. Commercialization and ESTD Activities

The funding provided by our EDA University Center grant enabled AMI to diversify our team in order to provide integrated business and engineering services. This integration is necessary to increase the probability of commercial success and significantly reduce the risks associated with developing new products and ventures. Specifically, the EDA grant helped AMI to add integrated business planning and design/engineering services and the ability to integrate voice of the customer into our product development processes.
These services can be divided into three areas of integrated activity: market understanding/business planning, technology and product development, and user-centered design.

Market Understanding/Business Planning services are intended to evaluate the business case for the project. AMI commercialization services are based on developing an understanding of the potential market for the product to be developed. Consequently, we can help a client to develop/evaluate strategic marketing plans, conduct comprehensive market research, analyze competition, analyze regulatory issues, develop/evaluate business plans, create financial models including the assessment of funding options, evaluate intellectual property, understand the value of key technologies, assess manufacturing/licensing options, and develop distribution channel strategies.

Technology and Product Development services are the base upon which our commercialization services have been built. These services include: proof-of-concept development; product specification development and product planning; detailed design and engineering analysis; computational modeling/simulation; and accelerated design verification, simulation and testing.

User-Centered Design is the heart of our strategy to increase the number of products that we help commercialize. These activities are intended to design products for specific users and uses. Our services include: observation based user research; function based styling; prototype development; defining a product language; platform development; and developing a product portfolio strategy.

6. Tie to the K-State MBA Program

In addition to the AMI internship program, K-State has developed a Technology Entrepreneurship Internship Program for students enrolled in the Technology Entrepreneurship Track of the K-State MBA Program. The MBA track in Technology Entrepreneurship allows graduate students to gain valuable exposure to the technology transfer process at Kansas State University through in-class teaching and an on-the-job program. The courses are open to all graduate students if space is available.

Since 2002 K-State graduate students interested in careers involving the creation and commercialization of innovation have taken part in a track of the MBA program that encourages specialization in Technology Entrepreneurship. In addition, a limited number of two-year graduate internships were created focusing on providing hands-on exposure to each stage of the innovation value chain: extramural grant creation and management, intellectual property disclosure and protection, intellectual property licensing and commercialization, and new product design and development. The overarching objective of the academic and experiential programs has been fostering a culture of technology-based entrepreneurship designed to have a positive impact on the local and regional economies.

The major obstacle in developing a program that imparts knowledge and skills necessary to accomplish the commercialization of early stage technologies is the widely distributed approach for innovation management employed by most non-profit research intensive enterprises,
particularly universities. The degree program and related internship have been in operation long enough to yield graduates who are actively participating in the licensing and commercialization of early stage technologies generated by the university. At K-State, these challenges were overcome by forming a partnership between the Colleges of Business Administration and Engineering, the university’s grant administration office, the university’s research foundation, and the technology commercialization organization (National Institute for Strategic Technology Acquisition and Commercialization, NISTAC). While students in the MBA program take courses in advanced entrepreneurship, technology entrepreneurship and strategy and new venture financing, students participating in the technology internship program during the first year “rotate” every three months to gain hands-on exposure at each of the four steps step in the innovation value chain. In their second year, technology interns may select a year-long assignment as the basis for gaining in-depth experience in an aspect of the innovation process they have chosen for their future career.

The Internship program provides participants with a broad perspective of the technology transfer process at K-State. In this program, selected MBA students rotate from the university’s pre-awards services office to Kansas State’s University’s Research Foundation and then to the National Institute for Strategic Technology Acquisition and Commercialization (NISTAC) and AMI. In the pre-award services office, interns assess grant proposals and contracts for compliance with university and federal grant regulations. At the K-State Research Foundation, interns assist in securing patents and managing a patent portfolio. Interns at the NISTAC center learn about technology licensing, acquiring donated technologies and creating startup companies to commercially develop such technologies. At AMI, interns assist the commercialization project manager in assessing technology-based business opportunities, developing marketing and commercialization strategies, and executing commercialization projects.

Based on the four years the program has been in operation, the result has been successful interdisciplinary collaboration using technology-based entrepreneurship as the vehicle for a coordinated program of in-class and experiential training that links faculty, graduate students, undergraduate students, and entrepreneurs together in a clinical program of teaching and practice.

7. Example Projects

Below are a few short examples of projects AMI has recently undertaken to assist entrepreneurs and businesses with developing and commercializing their products.

**WARM** An entrepreneur had an idea to provide clean, warm air in controlled volumes and temperatures to point-of-use applications throughout a home. The system is similar to a central vacuum system and is targeted for use in high-end homes. AMI helped define a commercialization strategy, brand the product, develop the prototype system, create the business plan, find capital for the business, and are supporting the installation of the pilot system in a $2.5M home in Kansas City. For more information, visit the web site AMI developed at [www.warmaura.com](http://www.warmaura.com).
AMI is currently working with a team of university researchers who have created a device to inform motorists of construction delays on rural highways. The Kansas Department of Transportation is highly interested in this product and is investing in its development. Upon completion of the project, they expect to promote its use in Kansas to increase highway safety and reduce motorist frustrations. AMI is taking a lab-based prototype and hardening the product, creating the commercialization strategy, and will be involved in developing the market and producing the initial batches of product.

A successful entrepreneur had an idea for a new exercise machine. Though he was already a successful businessman, he did not have access to the design and engineering resources he needed to capture his concepts in a prototype. The entrepreneur was a bit unsure of working with AMI because he had paid other groups to work on his project and was no closer to realizing his product. AMI formed a team of three staff members and eight students to conduct a deep dive. A Deep Dive is an intense brainstorm session used to quickly immerse the entire team in the project to: observe, brainstorm and prototype. At the end of a week-long effort, we shared our concepts and prototype with the entrepreneur who was very pleased with the results. Our industrial designer then transformed those ideas into a graphical representation that the entrepreneur is using to raise capital for the company. In addition, we have connected the entrepreneur to a rural Kansas company that has the expertise to manufacture the product and a North Carolina company that will co-develop the controls.

AMI staff and interns worked with an entrepreneur to develop a product that enables horse trainers and owners to remotely control the reins of a horse without being on or near the animal. It also enables the rider to dismount and keep tension on the reins sufficient to “park” the horse and keep it from wandering off while the rider attends to cattle or other ground activities. A team of mechanical and electrical engineers developed and refined an operational prototype while a group of marketing interns developed a strategic marketing plan which would enable the client to leverage limited time and money in order to maximize product launch. The Discovery Channel recently named the product as one of its top 25 inventions of year.

In the early 1990’s the American Institute of Baking (AIB) approached AMI about the possibility of employing recent advancements in machine vision in order to “grade” the quality of the “crumb” of bread being baked in production bakeries. The “crumb” is the level of porosity in the interior structure of a slice of bread. This measure directly relates to a number of baking parameters and ingredient conditions. AMI worked with KSU engineering faculty to develop the first generation of this machine, which was then marketed to the baking industry through AIB. Advancements in imaging, lighting, and processing technologies since that time have made the original design obsolete and unsupportable so AIB pulled the original design from the marketplace. Seeing that there was still a need in the marketplace for this technology, AIB has once again engaged AMI to develop the next-generation of crumb scanning equipment, known as CrumbScan Plus. AMI staff and ME and EE interns are currently collaborating with AIB’s R&D department to design and prototype an improved and more robust and manufacturable design. This new design will integrate a number of advanced technologies and be brought to market through a future commercialization arm of AIB.
An entrepreneur had an idea for a remotely operated decoy to attract wild turkeys. AMI worked with the entrepreneur to determine if the market would support the product, helped to develop the business plan, investigated prior art, designed the product, created the prototype, facilitated the manufacture of 100 units for test marketing, and secured the test market outlet.

A local electrician found the process of locating new outlets and switches in new construction to be slow. He asked AMI to help him design an inexpensive jig to locate these boxes quickly and easily. AMI investigated previous patents, developed a prototype, helped to open some test markets, created marketing materials and are producing 100 units for a test market.

An entrepreneur conceived the idea for a chair capable of being adjusted to accommodate a wide range of users (up to 95% of the male population down to the smallest 5% of the female population) and still maintain proper ergonomic positioning. AMI staff and mechanical and manufacturing engineering interns designed the pneumatically controlled adjustment system and then prototyped the chair for testing. Since that time AMI has produced a number of additional prototypes in order for the client to send the units out for field testing. One of the entrepreneur’s future potential markets is in the professional sports marketplace where there is a wide range of seating requirements in situations where a limited number of seats are available.

The Kansas Highway patrol needed to replace an old seatbelt convincer, but the company that used to manufacture the machine was out of business. AMI redesigned the Convincer to be easier to operate and manufacture than the previous version. By word of mouth, other safety agents started requesting units. We have now developed the ability to provide, with some manufacturing partners, seatbelt convincers to the marketplace. Students have helped to develop and execute a marketing strategy and support product sales of more than $250K. (See www.seatbeltconvincer.com)

8. Education Impact

Regardless of whether a project actually results in significant sales, students are involved in significant commercialization and ESTD projects. There are two key student groups that benefit from this program: engineering and business students employed in AMI’s intern program; and students enrolled in the technology entrepreneurship track of K-State’s MBA program. More than 40 students each semester are participating in AMI programs.

The program provides two significant educational benefits for students involved in the program. The first is a significant, direct experience in developing a product for a given market under real constraints. Furthermore, since interns typically work for AMI for about two years, each student
is typically involved in three to five of these projects during their tenure with the organization. The experience is further enhanced by the mentoring they receive from experienced staff members who have successfully completed many similar projects.

The second key educational impact of this program is a significant exposure to the trials and triumphs of technology entrepreneurship and working in a small business. By assisting others realize their own dreams, AMI interns learn first hand about bringing a new product to market and building a technology-based business. In addition, students are exposed to small businesses and become more likely to consider working for a small business upon graduation.

For a discussion of some of the more specific educational enhancements provided by AMI’s program, the reader is referred to some of the papers we’ve presented at other conferences.  

9. Economic Impact & Sustainability

Being a relatively new program, we expect that the number of products that are brought to market and the number of companies to be formed due to our work will increase significantly during the next few years. After just one full year of operation we found that AMI helped our clients increase sales by $2,630,000 and reduce costs by $1,277,000. We also helped create more than 42 jobs and retain 80 jobs. *(Results from 42 surveys completed in 2006.)*

It remains to be seen whether this activity can sustain itself. To date, the program is roughly covering the direct cost of operation, but could not sustain the organization infrastructure to keep the program going. Currently, AMI would not be able to stand on its own without the annual funding of our partners and the grants that we have received from the U.S. Economic Development Administration and the National Science foundation.

Our present model is to charge our clients for the direct time we have in each project. This means that the best one could ever hope for is to obtain 100 percent of the funds needed to operate the program when each person in the organization is working 100 percent of their time on client projects. In practical terms, this state can never be achieved.

There is some potential for AMI to actually earn more than the cost of each project. We are currently working to determine ways in which we can charge rates that include compensation for organization overhead activities such as meetings, leave, and prospecting time. Furthermore, we are exploring ways that AMI might be compensated based on the value of the work we do for our clients instead of on the cost of our work. Though some contracts are in place that will test this strategy, it is still too early to determine whether we will generate significant funding from these contracts to support the organization.

Furthermore, AMI has the capability to produce and sell a limited number of products directly to the marketplace. This capability allows the organization to sell products at a price greater than the direct cost of production. Though we do not expect to become self-sustaining this way, the effort helps cover the cost of our overhead. Sales of the seatbelt convincer mentioned above exceeded $250,000 in 2006. In addition to financial support, it must be noted that each of these efforts involves students to develop and implement marketing strategies and to handle the
business of delivering and supporting products. Furthermore, if product sales grow beyond AMI’s capacity, the university would “sell” the business and earn a financial return on the sale that would be used to sustain the organization.

Finally, it should be noted that AMI’s capability and activity provides an outlet to the university community to produce and sell products that would not make it to the market otherwise. For example, if a university invention is determined to have a limited market, perhaps a total of $1M in sales (limited lifetime). The university would most likely not invest in a patent nor is it likely to cause the inventors to drop what they are doing and start a company. On the other hand, if AMI can take that invention and develop it for the market and produce the product for under $500K, then up to $500K could be realized as an income for the university that could be distributed to the inventors, the university, and AMI. Furthermore, the activity increases the churn of product and technology development and fuels a culture of entrepreneurship at the same time that students are being educated and given a real experience in bringing real products to the marketplace.

**Results and Conclusion**

AMI has created a commercialization and early stage technology development activity that is transforming ideas into market-ready products. This activity supports entrepreneurs, existing businesses, and university researchers. In the process of conducting these projects, students are involved in both the technical and business aspects of working on real technology and product development projects. Students work in multidisciplinary teams and are exposed to real problems and opportunities that are directly impacting the Kansas economy. Former students are now engaged in handling multi-million dollar licensing negotiations on behalf of the university, marketing university-owned technologies, and developing and implementing commercialization strategies.

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**References**


