2006-956: AN EFFECTIVE PARTNERSHIP BETWEEN UNIVERSITY AND INDUSTRY: FULFILLING ACADEMIC AND CORPORATE ENGINEERING GOALS

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ABSTRACT

A multidisciplinary team of students and faculty from the School of Engineering & Mines at the University of North Dakota (UND) have partnered with Imation Corporation to conduct research on precision engineering projects. The cooperation between these groups has established a successful, unique, effective, and synergistic program that would not be possible without the contributions of each partner. The projects have been ongoing for four years and continue to evolve. The lessons learned from this experience are presented to share insights learned on developing long-term professional relationships between university and industry partners. Topics include the choice of appropriate projects, the use of capstone design courses, the contributions of graduate students, opportunities for internal and external funding, management strategies, and dealing with intellectual property ownership issues.

Thus far, the collaborative projects have dealt with the winding of digital tape media. These tape packs are used in many storage settings where high capacity and secure storage are essential. To meet the ever-increasing storage needs of the computer industry, the tape storage devices must be constantly improved, and innovations must be incorporated into the design and manufacturing processes. Digital tape storage is one key market for Imation, and as the sole U.S.-based manufacturer of digital storage media, digital tape manufacturing brings many engineering design challenges. The nature of these challenges and their possible solutions are exactly what students should encounter within capstone design courses and graduate projects in order to receive a "real-world" research and development experience.

To date, five senior-level capstone design student teams and one graduate student have been involved with the projects. The choice of appropriate projects is the most important component to an effective industry/university partnership. It must meet the educational needs of the course while simultaneously being of significant interest to the industrial partner. In most cases, it is appropriate that the project is a high-risk, high-reward project that is not time critical to the company, since meeting strict schedule commitments is very difficult in the academic environment. At the University of North Dakota, the project must have a significant design component, and a prototype must be designed, analyzed, built, tested, and used for its intended purpose. This R&D effort has also been instrumental in establishing a relationship from which to build internal and external funding opportunities for students and faculty. All partners have had active roles in advising the students and managing the projects. Weekly teleconferences along with periodic site visits to each facility for design reviews have worked well. The final critical issue discussed in this paper involves establishing ownership rights on the intellectual property that is jointly developed.

I. Introduction

In order to have an effective partnership between a university and a company, both the academic and corporate goals must be fulfilled. The lasting relationship between the University of North Dakota (UND) and Imation Corporation has been maintained due to the mutual benefits received by both partners. This paper outlines some of the critical aspects of a partnership that we have fostered over several years and, hopefully, provides some guidelines in establishing long-term industry/university ties. The topics discussed in this paper are the choice of appropriate projects, the use of capstone design courses, the contributions of graduate students, opportunities for internal and external funding, management strategies, and dealing with intellectual property ownership rights for this and other successful projects. These six issues have been identified as key factors, and each is discussed in detail. To provide a concrete context for the discussion, highlights from past projects are provided.

The UND/Imation partnership was initiated when select Imation personnel were invited to campus in 2001 by the Dean of the School of Engineering & Mines, Dr. John Watson. The Imation representatives toured the university engineering laboratories and spoke with a number of engineering faculty to determine mutual interests. The visit served as a chance for both parties to discuss their activities and capabilities with the intent of identifying synergistic activities. The visit resulted in identifying two areas of mutual interest; one in Electrical Engineering and one in Mechanical Engineering. The Electrical Engineering connection was with image processing and machine vision, in which Dr. Richard R. Schultz performs research in digital signal and image processing and analysis with his students. This fit well with the development of machine vision technologies at Imation for quality assurance and quality control, as well as the desire to increase the inspection rate and accuracy within their production line. The Mechanical Engineering connection occurred with the Vibration and Precision Engineering Laboratory (VPEL), where Dr. William Semke and his students work on multiple contemporary research projects in ultra-precision technologies, space hardware design, precision vibration control, and smart actuator development. Initially, Imation had an interest in Dr. Semke's precision measurement capabilities and simulation expertise for use in the manufacture of tape winding equipment and supplies that require a high degree of accuracy and precision.

At this point, Drs. Semke and Schultz visited the Imation manufacturing site in Wahpeton, North Dakota, to see their development and production facilities. During this site visit, several discussions with plant and section managers helped focus the next steps to take in identifying joint projects. The Imation personnel at the time consisted of Dennis Gladen, Plant Manager, and James Albrecht, Components and Mechanical Systems Manager. The trip also provided an opportunity to meet with individuals on a one-on-one basis, to provide an atmosphere from which mutual trust and respect could be grown. There was a commitment made to move forward on the collaboration by the UND faculty and Imation management. This commitment from Imation management provided the necessary resources, both in financial support and dedicated personnel time, representing a critical first step in building the partnership. Both groups also discussed what they expected to gain by the partnership. UND initially wanted to provide a real-world engineering experience for its capstone design sequence and use successes in this area to build a sustainable graduate-level research program. Imation was

looking for innovative solutions to ongoing technical issues within its production facility, in addition to training potential employees with the technical skills required by their operations. Both partners also recognized the potential financial opportunities that a industry/university partnership brings to the table. Along with this, the potential conflicts that arise from Intellectual Property (IP) issues were addressed. The first step was identifying and scoping capstone design projects for seniors in electrical and mechanical engineering. As the partnership has evolved and matured, involvement has been extended to include invited presentations, cooperative education experiences, graduate research assistantships, and external funding proposal submissions.

II. Choice of Appropriate Projects

The most crucial component of successful industry/university collaboration is the choice of project. It must meet the educational needs of the academic department while also being of significant interest to the industrial partner. In most cases, it is appropriate that the project emanates from a current or anticipated problem faced by the company. Furthermore, the project should be both high in risk and high in reward, but not time critical to the industrial partner. In engineering programs, the course goals should meet a majority of the ABET outcomes for continued accreditation. ABET accreditation is an assurance that a college or university program meets the quality standards established by the profession for which it prepares its students. The current ABET outcomes that have been established are provided in Table 1. In the capstone design course sequence, all outcomes should be addressed through an appropriate design experience, as accomplished throughout the UND/Imation projects.

Table 1. ABET outcomes[1]

A	An ability to apply knowledge of mathematics, science, and engineering
B	An ability to design and conduct experiments, as well as to analyze and interpret data
C	An ability to design a system, component, or process to meet desired goals
D	An ability to function on multi-disciplinary teams
E	An ability to identify, formulate, and solve engineering problems
F	An understanding of professional and ethical responsibilities
G	An ability to communicate effectively
H	The broad education necessary to understand the impact of engineering solutions in a global and societal context
I	A recognition of the need for, and an ability to engage in life-long learning
J	A knowledge of contemporary issues
K	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

The industry partner also has corporate R&D goals for the project that must be met. Primary industry goals include the involvement of intelligent, resourceful students to investigate projects that are of interest to the company, the development of a capable trained workforce, access to faculty expertise and resources not found in the industrial setting, and the continued professional development of corporate personnel. Through the course of our partnership, there have been various levels of student expertise and interest along with personnel changes and economic fluctuations. Both parties have been understanding and accommodating through these changes and a greater appreciation of the respective cultures has been found.

A key factor that must be maintained is that the university is not just a consulting firm providing work-for-hire. It is an educational entity first and foremost, which places serious limitations on student and faculty time due to other teaching, research, and service commitments. Faculty advisors typically spend two to four hours per week directly on the project and industrial advisors spend an equal amount of time. These commitments do not include the additional time necessary for site visits and paper and proposal preparation. In the current relationship between the University of North Dakota and Imation Corporation, this has been handled very well, and it is a major reason for the continued success of the partnership.

III. Capstone Design Courses

Within both the B.S. electrical and mechanical engineering programs, there are two-semester capstone design sequences in which students work on open-ended design problems for a complete academic year. At the University of North Dakota, each senior design project must have a significant design component, and a prototype must be designed, analyzed, built, tested, and used for its intended purpose. The capstone design course descriptions for the UND EE and ME departments are shown in Fig. 1, respectively.

> EE 480. Senior Design I. 3 credits. First course in the two-course capstone design experience for the electrical engineering undergraduate degree, emphasizing design methodologies, systems engineering, teamwork, and oral/written/interpersonal communications. Emphasis will be placed on oral presentation and written report generation with critique.
>
> EE 481. Senior Design II. 3 credits. Second course in the two-course capstone design experience for the electrical engineering undergraduate degree, emphasizing design methodologies, systems engineering, teamwork, and oral/written/interpersonal communications. Emphasis will be placed on oral presentation and written report generation with critique.
>
> ME 487. Engineering Design. 2 credits. The first course of a 2 course sequence in Engineering Design, establish concepts and important features of the machine or system, do market analysis, establish design objectives, explore alternatives, conduct research, specify constraints.
>
> ME 488. Engineering Design. 3 credits. Systematic study and practice essential to the optimal design of a complete machine or system, utilizing economic and social constraints together with current mechanical and thermal design techniques.

Fig. 1. Capstone design course descriptions for EE and ME.

Optimally, these capstone design experiences at UND are sponsored by industrial partners. Teams of EE and ME Senior Design students work with UND faculty and Imation Corporation personnel on joint projects. Ideally, the students involved with the university research projects first begin their experience with a cooperative education position to become familiar with the technical issues faced by Imation in their manufacturing processes. This allows each student to return to the university with a newfound knowledge of the challenges faced by industry, making that person a more prepared engineer after graduation. This individual also learns the leadership skills necessary to carry out the Senior Design projects that follow. Near the completion of their cooperative education experience, the students give presentations of their accomplishments to a large contingency of key Imation and UND

personnel at the Imation Wahpeton site. These activities have helped foster long-term relationships with strong interactions between industry and academia. The cooperative education students typically hold six-month appointments at the Imation facility. These appointments have been strategically aligned with projects of interest to UND researchers and Imation corporate needs. To date, three students have had coop experiences at Imation prior to their involvement in the capstone experience.

In the first semester of Senior Design, the students are exposed to a number of possible projects. These include both industry-sponsored projects as well as faculty-initiated research projects. A faculty member serves as the university advisor, and there are also industry advisors, where appropriate. A uniform format for project descriptions has been implemented in the EE Senior Design course that provides a fair, unbiased exposure of all projects to the students, as shown in Fig. 2. The standardized one-slide overview of each project is presented to the students, and they rank their interest in each project. At this point, the instructor of the Senior Design course tries to align the student preferences and capabilities to the proposed projects. Every effort is made to match student preferences to projects; however, some students must be assigned to projects that they did not prefer for the sake of accommodating as many projects as possible. Also, some projects may not have sufficient support and must be eliminated, since there are often more projects proposed than there are students available.

Following project assignments, the students begin to meet in their teams for concept development and trade studies. Preliminary designs are established and appropriate analysis is conducted to prove their effectiveness. By the end of the first semester, a "final" design has usually been completed. It is documented in a semester report that includes the development of the design along with the appropriate analysis and drawings. Additionally, an oral presentation is given as a critical design review outlining the progress to date on the final design. This design is reviewed by the project team and advisors, who provide comments and suggestions. If approved, orders are placed for components to arrive over the semester break and Computer Aided Design (CAD) files are sent out so that parts can be fabricated.

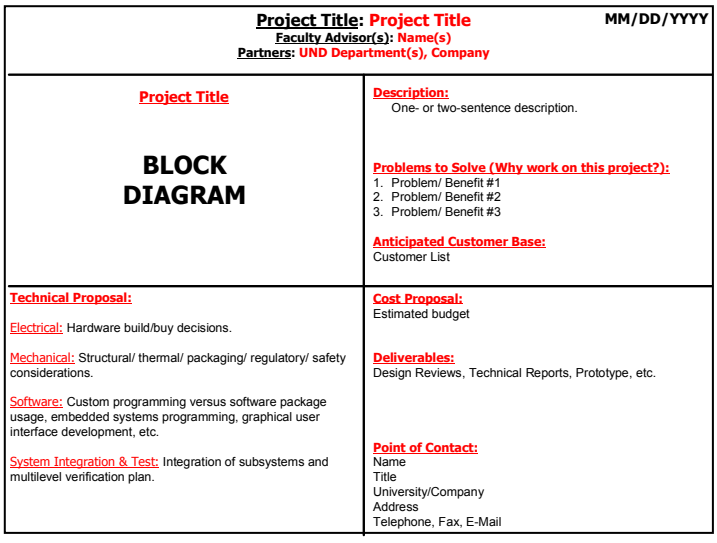

Fig. 2. EE Senior Design one-slide project description format.

Ideally, during the second semester of Senior Design, the students begin the construction of a prototype. In many cases, this where differences in the theoretical design and the actual product are discovered. It is also an opportunity to learn additional lessons in the complete design and build process from start to finish. After appropriate redesign resulting in modifications, the final troubleshooting begins. Often, this is a frustrating and time-consuming process for the students, but it is inherent to any engineering project. Following this stage of development, extensive testing and data collection are desirable. To use the device for its intended purpose is a rewarding experience and provides a sense of closure to all those involved. Again, a written summary report is generated and a final overview oral presentation is given to summarize the design process over the entire academic year and to deliver the essential project documentation.

IV. Graduate Students

The next incremental step to be taken is to attract highly-qualified graduate students to participate in advanced research and development for mission-critical information storage devices for Imation. Ideally, they would have been involved as undergraduates, but external student recruitment is often necessary and can bring fresh ideas to the project. Again, appropriate projects have to be found that have sufficient technical scope and depth for a graduate thesis, yet also fulfill a development need of the company. The ability to establish appropriate projects within the scope of the students' abilities and interests is a critical component to make any university project a success. The relationship between the project needs and thesis requirements are made such that they have as much overlap as possible. The overlapping mutual benefit to student and project creates a win-win situation in which both the university and industry partners are satisfied. This situation is sometimes hard to achieve, especially when other factors such as scheduling and class loads become priority issues for the students that need immediate focused attention. This is a common issue that large university projects face, and it is critical that all parties be aware of the limitations that are inherent to the academic environment.

Graduate student projects are generally larger in scope and involve a higher level of theoretical research on contemporary issues. At UND, most engineering graduate students are in the Master's program in their respective departments, which typically includes a written thesis and oral defense. In addition, the school offers the Ph.D in Engineering degree. In these programs, it is expected that the students are aware of current trends in the research area and utilize contemporary techniques for the advancement of state-of-the-art technologies in their respective research areas. This includes appropriate literature reviews, advanced analysis techniques, numerical simulations, and experimental investigations, where appropriate.

Ideally, the graduate students working on Imation-supported projects will also conduct research and development at the Imation facility for a minimum of three months per calendar year. This is an excellent workforce development model to produce the next generation of highly-qualified scientists and engineers, in which graduate education and the ability to work both independently and as a member of multidisciplinary teams are required. Ultimately, one of the long-term goals of this partnership is to further promote graduate-level education within the University of North Dakota School of Engineering & Mines, through corporate funding

and premiere career opportunities at Imation. Maintaining the professional relationships between UND and Imation Corporation is critical in sustaining and growing this partnership.

V. Funding Opportunities

The work with Imation has strengthened the research capabilities of UND and has helped establish a successful and productive research environment that is well-positioned to seek out external federal, state, and local government funding opportunities. This has been established through strategic purchases of appropriate equipment in the research labs with university funds, Imation financial support for graduate students and Senior Design projects, and the use of specialty Imation equipment essential to the studies being conducted. The dedication of the faculty and Imation representatives to these activities should also be duly noted. Several federal agencies can now be effectively targeted for the submission of research proposals. Grant Opportunities for Academic Liaison with Industry (GOALI), a National Science Foundation (NSF) program, is especially appropriate for the activities at UND with Imation. The GOALI initiative aims to synergize collaborative research partnerships by making funds available to support an mutually beneficial mix of industry/university linkages. Industry can outline new technical challenges and assist in the support of academic institutions. By serving as a catalyst for industry/university partnerships, NSF helps ensure that intellectual capital and emerging technologies are brought together in ways that promote economic growth and an improved quality of life in the United States[2].

An opportunity unique to UND in Grand Forks and the Imation Corporation facility in Wahpeton is the Red River Valley Research Corridor. The Research Corridor is an initiative established by U.S. Senator Byron L. Dorgan to attract high-tech firms and research funding to North Dakota that have an emphasis on science and technology, and on applied R&D to help develop the University of North Dakota and North Dakota State University into more competitive research institutions[3]. Strong basic and applied research programs will undoubtedly be critical to the success of Senator Dorgan's initiative. Another vital component will be the broad range of academic programs offered among the partners, particularly in the arts and humanities that contribute so strongly to quality of life in the region. As stated by UND President Charles Kupchella, "In its fullest realization, this Corridor would promote research opportunities, resource sharing, development and training among partners in education, business, industry, and government in North and South Dakota, Minnesota, and Manitoba[4]." This collaboration with Imation strengthens an important industry/university partnership within the Corridor, and helps the partners leverage additional resources from other federal, state, and local government agencies. These types of "program seed" activities at UND already share a legacy of successful collaboration through the longstanding NSF EPSCoR (Experimental Program to Stimulate Competitive Research) program, active in the state of North Dakota since 1986.

VI. Management Strategies

Throughout the partnership between Imation and UND, several effective project management strategies have been developed. These strategies are conducted in cooperation with the Senior Design classes. The Senior Design teams typically have weekly one-hour teleconference

meetings and periodic plant visits to Imation-Wahpeton each semester. Prior to these teleconferences, an agenda is sent out to the participants that highlight the week's accomplishments and specific items to be discussed. After the meeting, a summary of the discussions and agreed-upon action items for the participants are distributed. These activities supplement the design course requirement of weekly progress reports, indicating goals and identifying accomplishments. Traditionally, the teams visit the Wahpeton plant at the start of the fall semester to visit the production line and gain a better understanding of the opportunities and challenges faced by a highly successful digital media manufacturing facility. Additionally, as part of the course requirements, an end-of-semester review is given to the industrial partner. Typically, the fall semester review is held on the UND campus, with four to eight Imation representatives traveling to Grand Forks to participate. In the spring semester, the UND team of students and advisors travel to the Imation plant in Wahpeton for a final presentation to 15-20 Imation engineering personnel. This also provides an opportunity to use and/or install custom-designed components in the industrial environment.

VII. Intellectual Property

Intellectual property ownership often becomes a significant issue whenever university and industry cooperative research is conducted. If there is the potential for significant scientific discovery and economic impact, these issues must be discussed with appropriate agreements negotiated up-front. Of course, it is extremely challenging to craft a joint intellectual property ownership rights agreement before any collaborative R&D has taken place. Academic freedom to publish is a critical aspect of student and faculty development within academia, while confidentiality and intellectual property protection are essential to the industrial partner. These fundamental differences in culture – "publish or perish" in academia and "protect or perish" in industry – are where the difficulties lie at the industry/university interface. Therefore, a high priority review process is needed that can approve the dissemination of material into print or electronic media in a timely fashion. Other significant issues include naming the assignee to an invention, applying for patents and trademarks, costs associated with filing, prosecuting, issuing, and maintaining patents, commercializing inventions, and negotiating an exclusive or nonexclusive license with the industrial partner that has a fair royalty revenue stream back to the university. If federal funding was utilized to conduct the research, the cooperative research agreement is also subject to the rights of the federal government set out in chapter 18 of Title 35 of the United States Code (i.e., the Bayh-Dole Act), section 401 of title 37 of the Code of Federal Regulations (i.e., the codification of the Bayh-Dole Act), and section 650.4(a) of title 45 of the Code of Federal Regulations (i.e., the National Science Foundation's patent rights clause), with the rights of the parties governed by the laws of the state where the research was carried out. Additionally, the federal government holds a nonexclusive, royalty-free license to any invention created by its support, and this can truly complicate matters for the industrial partner.

Although each academic/industrial relationship is unique and no one agreement is applicable in all cases, for starting negotiations between the university and an industrial partner, the NSF supplies a sample cooperative research agreement on its Web site at http://www.nsf.gov/eng/iucrc/sample_agreement_form.jsp. This agreement is supplied in support of the NSF Industry/University Cooperative Research Center (I/UCRC) program, but

it is an appropriate document to help initiate discussions on most industry/university agreements and was utilized in the preliminary Imation/UND discussions.

VIII. Project Highlights

The Information Storage Industry Consortium (INSIC) has identified tape transport technology as a key area of concern in the digital storage manufacturing industry. As the areal density of the tape increases at an exponential rate, the industry has made significant changes to meet these ever-increasing needs. The INSIC report goes on to say that the "meat of the problem" is lateral tape motion (LTM) and longitudinal tape motion. Although not fully understood, the primary causes of lateral tape motion have been identified as the tape edge geometry, tape path mechanics, pack wind quality and air entrainment, position error signal (PES) generation and quality, servo actuator performance, and the need for advanced guiding strategies. The primary longitudinal tape motion issues are tension and velocity control, back-hitches, and variable tape path length due to air entrainment. INSIC goes on to provide suggested areas for further research, including Tape Edge Morphology, Pack Formation, Lateral Position Signal Quality, and Head Actuator Performance[5].

The active participants on the UND campus are Dr. William Semke, Assistant Professor of Mechanical Engineering, and Dr. Richard R. Schultz, Associate Professor and Interim Chair of Electrical Engineering. Both individuals have had essential roles in the work with Imation over the past several years and look forward to continued success. Administrative and technical Imation personnel from the corporate headquarters and manufacturing locations have been active throughout the past several years and have been significant contributors instrumental in the partnership's success to date. All parties have expressed a great willingness to cooperate on future projects, and appreciate the added value from the team members at both Imation and the University of North Dakota. There is a strong, established record of active, productive participation and cooperation on the projects described in this paper.

A brief description of several of the projects undertaken over the past academic years during the partnership follow, along with some of the lessons learned from each.

The first year of the partnership began with two individual projects, one for EE Senior Design and one for ME Senior Design. As a representative example of the type of projects that have been undertaken, the electrical engineering project involved the design and fabrication of a charge amplifier. This custom built system monitored pressure in the plastic injection molding process using a computer interface to monitor multiple inputs (Fig. 3). The system was a less expensive alternative than existing commercial-off-the-shelf instrumentation, and it was customized to meet Imation's needs. Two EE Senior Design students participated along with primary and secondary Imation advisors.

Fig. 3. 2002-2003 EE UND/Imation Senior Design project. Left: Injection molding work station. Right: Graphical user interface for the charge amplifier system.

The mechanical engineering project involved evaluating and recommending possible solutions for a noncontact measurement tool to determine the run-out of Imation data tape spools. An accurate, reliable, and repeatable system for capturing measurements was needed, along with statistical methods used to analyze the data. Three ME students were on the team with primary and secondary Imation advisors. A proof-of-concept prototype system was developed, tested, and demonstrated the ability to capture data and provide the required statistical output. From these experiences, it was determined that a multidisciplinary team consisting of both ME and EE students would be beneficial for both the Senior Design project and Imation's goals. This is closer to what the students will witness in an industrial setting, and it provides a more realistic educational experience. In the subsequent years, integrated EE and ME projects have been preferred.

On other projects, Imation has taken experienced interns and integrated their summer projects into a senior design class project. In one particular case this allowed a senior design team to make great progress and significant advancements in a short time frame. The 2003-2004 team was fortunate to have an ME team member who already had an intern educational experience at the Imation-Wahpeton site on related projects prior to enrolling in Senior Design. This greatly increased the team's knowledge base on the project and led to faster development. On this project the team was made up of three ME students and one EE student. We recognized during the project that the ratio of MEs to EEs was not ideal, although it did not pose a significant problem during this project. With this experience later teams were formed with a more equal distribution of discipline.

The 2004-2005 Senior Design team had an equal number of EE and ME participants, and they worked very well together. Their skill sets truly complemented one another. One member had been an Imation intern previously, but the students senior design project was not directly related to their Imation intern experience. However, this still led to a better understanding of the issues faced by industry and provided some additional benefit.

During this time, an Imation-sponsored graduate student project was initiated. An Engineering Ph.D. student began research on modeling and simulation of nonideal tape windings. The traveling media problem is a long-standing investigation in engineering and industry. The parallel theoretical investigations within the graduate program along with the experimental studies being developed and used in the Senior Design courses resulted in a comprehensive

study of this very important and challenging problem. Advanced mathematical studies and finite element simulations are being developed for comparison and correlation with the valuable data obtained from the experiments.

The current Senior Design team consists of three ME students designing a system to evaluate new and existing sensor technologies to dynamically measure a tape pack. One participant actively worked with a tape pack measurement tool during his intern experience at Imation and brought a wealth of knowledge back for Senior Design this academic year. The Engineering Ph.D. student has also been active in the development process, and has participated in the Senior Design meetings and presentations. Unfortunately, no EE students are participating in the project this academic year. However, it was not necessary to significantly alter the scope of the project to match the requirements and skill set of the participants, since the ME students bring both mechanical design and sensor/actuator experience to this project.

A host of beneficial aspects of the partnership can be listed across the academic and industrial interface. Recruiters, managers, and engineers from Imation Corporation continue to be invited to deliver on-campus seminars to the student chapters of the various professional societies, such as IEEE and ASME. For example, a Mechanical Engineering Ph.D. from Imation delivered a presentation to the students on finite element modeling challenges encountered at Imation, and how his activities in school have influenced his professional career. This was presented as part of the UND ASME lecture series, in which industrial and government employees are invited to campus to discuss career opportunities and to see how current classroom activities relate to real-world experiences. To maintain more frequent and in-depth interactions between the partners, videoconferencing short courses are planned in the future. Additionally, Imation expertise in quality assurance and quality control are to be incorporated into current courses at UND. These and other corporate training seminars and short courses will be provided to Imation employees and UND students. All parties have close ties to the success of workforce development in science and technology in this region of the country, and there is not doubt that an effective industry/university partnership between Imation Corporation and the University of North Dakota School of Engineering & Mines has enabled this to prosper.

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