AC 2011-119: CURRICULUM DEVELOPMENT FOR A CAD/CAM OPTION IN A MANUFACTURING ENGINEERING TECHNOLOGY PROGRAM

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Curriculum Development for a CAD/CAM Option in a Manufacturing Engineering Technology Program

The growth in sophistication and breadth of Computer-Aided Design and Manufacturing tools that are available today increasingly requires engineers and technologists who are specialized in their use if their full benefit is to be realized. CAD systems have over time included more and more advanced functionality. These have extended basic 3D parametric modeling, electronic drafting and surfacing tools to include a growing range of specialized Design-for-Manufacture (DFM) modeling environments and analysis tools. DFM tools for example include modules for sheet metal or injection mold design where the designer works with features that are relevant to the design domain so that the result can be manufactured accordingly. Analysis tools include the ability to model and simulate the kinematics and dynamics of mechanisms, Finite Element Analysis and Computational Fluid Dynamics. On the CAM side, sophisticated tool path generation programs are available for 5-axis machining and for tool path simulation and optimization. In addition specialized CAM modules are also available for programming multi-spindle and turret turning centers. Engineers and technologists must also cope with diverse and complex organizational structures for the design and production teams in which they must function which strongly impacts the management of CAD/CAM data. Consequently, their work increasingly requires the use of complex Product Data Management (PDM) systems. Finally, a CAD specialist might also be expected to be able to automate a CAD system using programming tools so as to improve design and modeling efficiency. It should be clear from the above that the skill set for an engineer or technologist capable of effectively using state-of-the-art CAD/CAM technology can be extensive. Traditional specializations can originate such a technologist from one of several disciplines the most likely being the Mechanical, Manufacturing or Drafting and Design routes. However, an argument can certainly be made for a unique and focused specialization in CAD/CAM.

This paper describes efforts towards developing such a specialization. This effort has been following a two-phased approach. The first phase currently underway involves taking an existing Industrial Technology program in CAD/CAM and converting it into an ABET accredited option in Manufacturing Engineering Technology. The strategy of rolling an unaccredited program into one that is accredited has been used in the past and has proved to be effective as a nursery for growing the new option both in size and quality before it emerges as a standalone program. The curriculum developed for the new MET CAD/CAM option will be presented and experiences in doing this will be described in detail. This paper will further explore the possibilities for the second phase of this effort, a standalone curriculum for an ABET accredited CAD/CAM technology degree. The logistical and resource challenges that are likely to be encountered in rolling out this program will be discussed.

Introduction

It is difficult to find a discipline today where technology advances are as rapid as the field of CAD/CAM. These are driven continually by combinations of new developments in several areas that include computer software, hardware, information technology and the fundamental theories behind geometric modeling, design and manufacturing. This has led to ever more sophisticated and powerful CAD/CAM systems that need to be mastered by practitioners in the field if their true benefit is to be realized in increased product development efficiency and quality. In addition,

with ever increasing demands on integration and concurrency in the product development cycle and in many cases globalization of the effort, CAD/CAM systems cannot be considered stand-alone systems. They are in fact key data authoring and manipulation tools that prepare data that is central to most other product development activities such as analysis, optimization, process planning, resource and production planning, supply chain management, marketing and advertising, and quality control. As such their use must be considered a critical function for any company that wishes to be competitive in creating products that will be successful in the global economy.

The above motivates the need for highly trained CAD/CAM technologists who can fully exercise the capabilities of these tools. While acquiring this expertise can be viewed as an ongoing and career-long endeavor the initial training that a technologist receives at a university is critical to setting the direction and motivating this process. It is within the context of such a program that the basic building blocks of the discipline and guidelines for their use can be established within the thinking and tendencies of novices. To properly lay this foundation an argument can be made for the creation of a program that focuses on this technology. This provides more exposure over the current approach where CAD/CAM is a specialization within other disciplines such as Mechanical or Manufacturing Engineering that is pursed through taking technical electives.

The Engineering Technology department at Western Washington University has a history in graduating students who specialize in CAD/CAM from its Industrial Technology (IT) program. The majority of these students find employment regionally in small and medium sized companies that specialize in product design and the fabrication of molds and tooling. There is an aerospace influence driven by companies that are part of the Boeing Company supply chain. Even with the economic downturn employment opportunities though not as abundant as before are available for graduates.

In spite of the viability of this program, state and university directives have necessitated moves towards accreditation of programs to ensure that graduates meet standards set by their professional governing bodies. For various reasons, the IT-CAD/CAM program has never been accredited. The rest of this paper will discuss the approach taken by WWU's ET department towards this goal. It will start by identifying the broad skillset required by technologists in the CAD/CAM field today that motivates the need for a program that is focused in this area. An overview of a new CAD/CAM option in the department's Manufacturing Engineering Technology program will be given as a first step towards creating an ABET accredited program. The experiences and challenges faced thus far will be discussed. The factors that will influence the decision to take the next step towards a stand-alone program will be presented.

CAD/CAM Technology Today

CAD/CAM systems have evolved today to a high level of sophistication. They can be broadly classified into two groups. The first provides a single environment that integrates the CAD and CAM functions "under one roof". Examples of such systems include CATIA, Pro/Engineer and Unigraphics. In the second group the CAD and CAM functions have been developed by independent vendors and the CAD model must be transferred between systems. Associativity is difficult to maintain and a significant amount of manual manipulation is required if changes are

made to the design. Examples of such systems include SolidWorks, Inventor, SolidEdge on the CAD side and MasterCAM, SmartCAM and GibbsCAM for tool path generation. Other than this distinction, these systems implement many of the same capabilities. These include:

- Feature-Based Parametric Modeling
- Assembly Modeling
- Generative Drafting
- Integration of Solid and Surface Modeling
- Photo Realistic Rendering
- Integrated Engineering Analysis Tools (e.g. FEA, Kinematics, Mold Flow)
- Integrated DFM Tools (e.g. Sheet Metal Product Design, Mold Design)
- CAD Automation Interfaces
- Prismatic Machining Tool path Generation
- 5-axis Machining Tool path Generation
- Multi-Axis Turning Tool path Generation
- Tool path Verification and Optimization

In addition to the above, CAD/CAM systems generate data that is typically co-authored by teams of engineers and technologists. This data must support a broad range of other product development functions within an enterprise. The need for data management and collaboration has given birth to *Product Data Management* (PDM) and more recently *Product Lifecycle Management* (PLM) technologies. Though logistically challenging to implement within a university setting, it can be argued that PDM/PLM should be an integral part of the exposure of students to the CAD/CAM discipline.

Skill Set for a CAD/CAM Technologist

Table 1 lists the desired skill set for a technologist in the CAD/CAM discipline. This encompasses a broad range of skills that go far beyond the ability to just use the software. An understanding of the central role of this technology in authoring and managing data in product development and its links with analysis are also critical. A deep appreciation of Design for Manufacture and Assembly is also necessary to ensure that modeling reflects shapes that can be cost effectively created and that drawings capture appropriate information to convey this meaning. Practioners must be adaptable to different modeling environments and be able to customize and integrate CAD systems with other engineering tools for greater efficiency. Programming and operation of advanced CNC systems particularly those that utilize 5-axis kinematics and combine turning and milling functions are essential.

	Desired Skill	Comments
1	An ability to efficiently model a wide range of products of varying complexity in particular those that require machining, joining and molding.	CAD/CAM graduates should be comfortable modeling in a diverse product development environment. Regionally there is a high aerospace and ship building focus.
2	Competency in generating engineering documentation from CAD models that conform to accepted drafting standards.	Not as broad as a technologist in the Design/Drafting area in applying standards. However, should be able to generate appropriate documentation to support fabrication.
3	Acquire a basic understanding of feature-based parametric, assembly and geometric and solid	These technologies are typical of systems used in the design of machined, welded and molded components. Contrast this

	modeling concepts that form the core of CAD/CAM systems.	with civil or architectural CAD where there is a greater focus on 2D and drawings.
4	Be able to organize and manage CAD data efficiently.	Assemblies can be large and require an understanding of referencing between CAD files. Assembly structures should promote efficiency in use.
5	Competency in utilizing various types of inputs to guide the creation of 3D CAD models.	3D laser scanning and sketch tracing are two techniques that provide inputs to modeling.
6	An ability to collaborate in creating CAD models and using these to fabricate tooling and components.	Modeling of large assemblies is typically a team activity. This complicates CAD data management. Should be competent in decomposing to distribute effort. Use of PDM is becoming more common.
7	An understanding of how CAD supports engineering design and analysis.	CAD is used as part of the design process and as input to analysis applications (e.g. FEA). A range of geometric analysis tools (E.g. curvature and draft analysis) are available to support modeling activities.
8	The ability to incorporate *Design for Manufacture* and *Assembly* requirements into CAD models.	Students need to develop the skill of modeling products that can be fabricated. This includes using draft for molded parts, proper sizing of threaded features and specifying fits on drawings for mating components.
9	Be able to generate, validate and optimize tool paths for manufacturing a wide range of products and tooling.	CAM tool path generation for turned, prismatic and free-form features. An understanding of manual part programming is necessary for programming simple parts and in verifying programs.
10	Skill in programming and operating CNC equipment for machining products and tooling.	Confidence in selecting tooling, setting up a CNC machine, loading and verifying a program, and running the part.
11	An ability to quickly adapt to different modeling environments.	Department supports several CAD systems in addition to CATIA (Pro-Engineer, SolidWorks, Rhino). Students are encouraged to learn these on their own as part of an independent study or senior project. ETEC 312 is an elective that uses Rhino.

Table 1. Skill Set for CAD/CAM Technologist

CAD/CAM as a Specialization

A review of different disciplines shows that CAD/CAM as a specialization most aptly fits within Manufacturing and Mechanical Engineering (E), and Drafting/Design, Manufacturing and Mechanical Engineering Technology (ET). This is not to say that the technology does not receive attention within other programs. In fact almost every discipline requires some product or process design work that will today be largely performed on a computer. Consequently an introductory course in CAD is typically a requirement for many disciplines. In Mechanical Engineering for example, this has replaced the traditional manual drafting class and is typically offered early in the program (freshman or sophomore years). In contrast introductory courses in CAM are offered more as part of a specialization (e.g. Design and Manufacturing within ME) and can also be taken as a technical elective by interested students (junior or senior years). This type of course would typically involve exposure to G and M programming for CNC machining. The author also has experiences with an introductory (sophomore) design and manufacturing course that includes CAM and the use of CNC trainers within a mechanical engineering program. In depth study of the technology is not possible with this approach.

More advanced CAD exposure may be sprinkled throughout other courses in engineering curriculums. Again using ME as an example, a course in Mechanisms Design could utilize a kinematics module within a CAD application to give students the experience of using simulation to validate theoretical results. A similar approach can be taken in a Machine Design course. However, the focus in these courses tends to be more on the theory than on the practical application of the technology. Technology programs offer a better opportunity for the latter.
Manufacturing Engineering Technology programs provide a good home for a focus on CNC and CAM. However, intensive CAD focus is difficult to fit in given the time constraints and accreditation requirements. The opposite is true for Drafting/Design Technology where the focus is on product design and the use of CAD to generate proper engineering drawings as part of the documentation for design. In depth exposure to different CAD system capabilities may be sacrificed in favor of breadth of exposure to a range of CAD systems. Exposure to CAM may be limited to a single course that includes an introduction to the programming of CNC machines. Application of the technology for tooling and mold fabrication is typically beyond the scope of these programs.

Rationale for a CAD/CAM ET Program

In should be clear from the above sections that (1) CAD/CAM technology today encompasses a broad and continually expanding set of capabilities that are available for use in these systems, (2) there is an extensive skill set that is necessary for practitioners in this discipline to be competent in, and (3) that there is currently no prescribed curriculum that is universally accepted for training technologists in this discipline. In addition to these points, the historical experience of IT-CAD/CAM graduates from WWU's ET department shows that there exists a high demand within a broad spectrum of industry for technologists with this training.

Why an MET CAD/CAD Option?

The decision to develop a CAD/CAM option within an existing program in Manufacturing Engineering Technology was based on the following factors:

- <u>The need to improve the quality of the IT-CAD/CAM program and opportunities for graduates:</u>
  A focus on CAD/CAM has been present for over a decade in WWU's ET department under the Industrial Technology umbrella. However, this program has never been accredited. Requirements by the Washington State Higher Education Coordinating Board and the University have made accreditation a priority to bring program curriculums into conformance with the standards set by their professions. Given the make-up of the ET department's faculty (mostly graduates from ABET engineering programs) and the fact that there are already three ABET accredited ET programs offered (Electronics, Plastics and Manufacturing), it made practical sense to purse accreditation with ABET rather than ATMAE. ABET accreditation also provides employment opportunities with Boeing one of the states leading employers that uses this as a requirement in their hiring criteria.
- <u>Prior experience in using options as a step in developing ABET accredited stand-alone programs:</u>
  The department has had previous success in creating an option within an existing accredited program as a stepping stone towards a stand-alone program. The Plastics Engineering

Technology (PET) program was first an option within the Manufacturing Engineering Technology program before becoming independently accredited in 2001. Currently the department is also experimenting with a Plastics Vehicle Technology option within the PET program in addition to the MET CAD/CAM option. This approach tests the water for creating these new programs and builds the case for additional resources driven by the enrollment of students in these options.

- Current resource constraints:
  Given current budget restrictions there is little likelihood of receiving state funding in the near future for supporting the creation of new stand-alone programs. A stand-alone CAD/CAM ET program with a minimum annual enrollment of 15 students would require at least one probably two additional full time faculty. Creating options allows curriculum to be developed and implemented at least partially without the need for significant additional resources. Faculty from the IT-CAD/CAM program become part of the MET program to support the option as the IT program is phased out.

Overview of Curriculum for an MET Option in CAD/CAM

The primary CAD/CAM related courses that form the core of the option are shown in Figure 1.

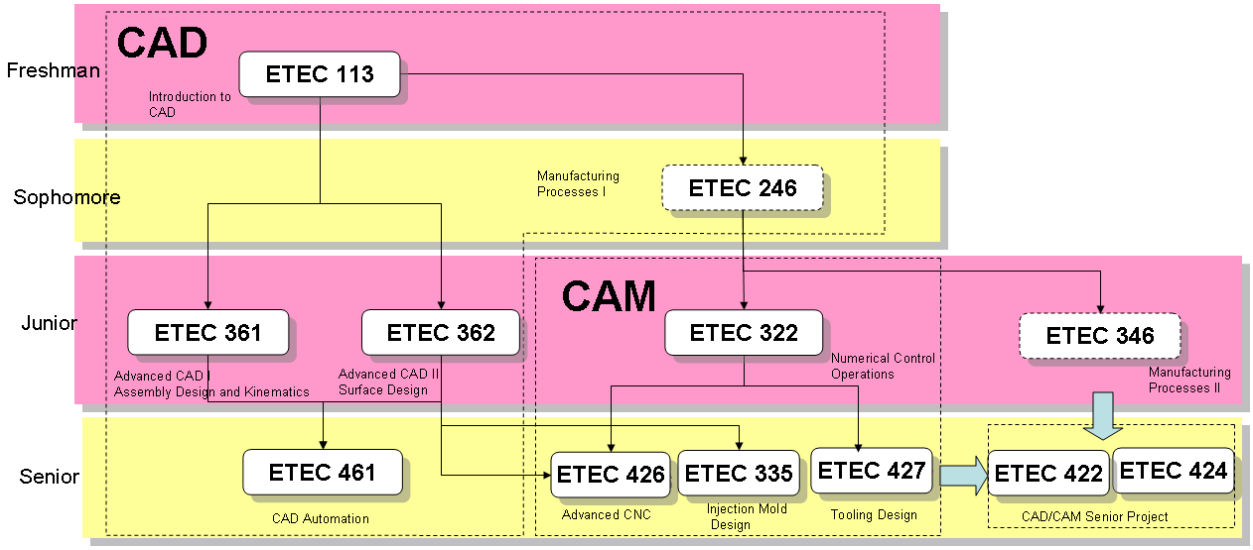

Figure 1. Key CAD/CAM Courses in Option

- Freshman and Sophomore Years:
  The bulk of these two years is devoted to math, science and engineering fundamentals. The CAD/CAM curriculum starts with an introductory CAD class (ETEC 113) that is taken by all ET majors with the exception of those taking the Electronics program. In this course students are introduced to the fundamentals of 3D Parametric Modeling and Generative Drafting. The CAD system used is CATIA. The rationale for this choice is based on a regional preference for this system that is driven by the Boeing Company. CATIA also supports an integrated approach to CAD/CAM which allows students to be exposed to associativity in data between design and manufacturing activities. Students get to use rapid prototyping software and equipment as part of a term project that for many is their first introduction to fabrication.

A new Manufacturing Processes course (ETEC 246 to be taught for the first time in Fall 2011) during the sophomore year will expose students to basic manufacturing processes. Labs in this course will require students to use different processes to fabricate an assembly with a combination of cast then machined and sheet metal parts. CATIA will be used to design sheet metal parts and to create drawings for them. These parts will be flattened and cut from sheets on a waterjet machine. Using the sheet metal design workbench in CATIA will expose students to modeling with the use of sheet metal features and help expand their understanding of the concept of *Design for Manufacture*. Both ETEC 113 and 246 are newly developed courses that have resulted from the need to consolidate sections with increases in class sizes due to budget cuts.

- Junior Year:

  Students are required to take two advanced CAD courses. ETEC 361 focuses on assembly modeling and mechanisms (kinematics). Students are introduced to advanced concepts such as skeletons and Work-In-Process (WIP) that are useful in managing the modeling of large assemblies. They are also taught how to add motion to assemblies using CATIA's DMU Kinematics Workbench[1] (note that this describes use of Pro-Engineer which was recently replaced with CATIA). The second advanced CAD course ETEC 362 introduces students to the modeling of free-form surfaces. This includes exposure to 3D scanning techniques that support construction of a surface model from a point cloud collected off a preformed shape. In addition to broadening the students understanding of the capabilities of CAD, both these courses encourage greater familiarity and confidence with basic modeling techniques and CAD data management.

  Numerical Control Operations (ETEC 322) teaches students both how to manually program CNC equipment and to generate code automatically using a CAM application (CATIA's Prismatic Machining Workbench). Students require basic CAD modeling skills from 113 and an understanding of machining from 246.

  A second manufacturing processes class ETEC 346 is scheduled to be taught for the first time in 2012-13. This course will focus heavily on material selection and DFM challenges that different manufacturing processes bring to the table. It is envisaged that this course will be driven by case studies provided by local industries. Project work will involve the use of CAD.

- Senior Year:

  A senior level CAD class ETEC 461 introduces students to the use of programming for automating the creation and manipulation of CAD models. Visual Basic for Applications and integration of the CAD environment with Microsoft EXCEL are key parts of this course[2].

  On the CAM side, a cluster of three courses further develops skills in this area. Of these, ETEC 426 focuses exclusively on advanced programming of CNC equipment using CAM generated data. Several flavors are alternated, the most common being 3-axis surface machining. The other two courses focus on the design and fabrication of injection molds (ETEC 335) and tooling and fixtures (ETEC 427). The former heavily utilizes both CAD and CAM in CATIA to design and machine an injection mold.

  Finally, each student must complete a senior capstone project (ETEC 422 and 424) that allows them to integrate the use of the skills they have acquired in the program. Extensive CAD modeling is a requirement of this project. Typically these projects also lead to the use

of CAM and CNC to fabricate a part or to create molds or tooling, though not always. Students may for example utilize 3D scanning and digitizing techniques to support their modeling, do CNC simulation and tool path optimization (all done on the computer) or enhance modeling efficiency by programming a CAD automation tool to assist, analyze and possible optimize a design task.

- Technical Electives:
  Students in the option are required to take 15 credits in technical electives. The available options are summarized at the end of this paper. These present groupings that allow students to gain greater experience in one of three areas or to be a generalist. The areas are:
  - Plastics Product Design and Processing
  - Manufacturing Automation
  - Business and Operations Management

  The last option fits well with students interested in doing a minor in Manufacturing and Supply Chain Management offered by WWU's business school. An approved grouping of math classes is also provided that is a subset of a Math minor. This can be taken by students who may wish to pursue graduate studies at an engineering school.

Discussion of the New Program

- Impact on Quality of Graduate: Given that the program has just been introduced it is not possible to provide any quantitative supporting data at this time. However, qualitative observations can be made from an advising perspective. First, the students re-declaring to the new option from the IT-CAD/CAM program (mostly juniors) have been those that have stood out in performance and motivation. The switch does not come without at significant price in additional courses and increased time to graduation. So understandably only those students who are passionate about the subject, driven to self-development and interested in receiving the best education will take this plunge. Second, students declaring for the first time (freshmen or sophomores) appear to be much more knowledgeable about the discipline, less intimidated about the requirements and more committed to the idea of becoming an Engineering Technologist. This is partly due to the fact that the IT-CAD/CAM program only specified around 120 credits for the degree (versus 144 credits for MET-CAD/CAM) leaving a lot of room for a student to pursue other interests through a double major or a minor. Also, the math and science requirements were less rigorous than the new program. This tended to attract students who were undecided and less committed to a career in technology.
  It must also be recognized that one of the impacts of the *Great Recession* may be to redirect higher caliber students from more expensive university programs to ones that are more affordable. WWU is recognized as offering one of the most affordable degrees in the Pacific Northwest region. Coupled with better employment opportunities for technical fields, this too will positively impact the quality of students seeking any ET major.
- Managing Program Size: Twenty students have enrolled in the major in this first year of which five have re-declared from the IT-CAD/CAM program which is now off the books. It is anticipated that a manageable size of the program given available faculty and lab resources is forty students. This would bring the total of students pursuing a Manufacturing Engineering Technology degree to around 120. It is unclear at this time how much the new

option will impact enrollment in the core MET program. It is anticipated that there will be some attrition there as students opt for the CAD/CAM option. There is also a noticeable recent increase in enrollment in ET programs overall. This can be attributed to trends in the job market where employment opportunities in technical areas are likely to be better as the economy rebounds. All signs point towards class sizes that will challenge available resources. Currently only one program within the department uses entry requirements to manage enrollment. This approach may need to be adopted in the future for the MET program should size become an issue.

- Resource Challenges: Recent curriculum changes have consolidated introductory CAD instruction into a single course (ETEC 113). This has been partly driven by budget cuts. The ET department now conducts class sizes of almost 50 students for ETEC 113, offered once per term (3 times per year). This class is run by one instructor in a single lab with the support of TAs. This is a significant shift from running multiple smaller sections with different instructors. It remains to be seen if reduced availability will have a negative impact on accessibility. Advanced CAD classes are rarely larger than 25 students and easily fit in the available space. The biggest space challenge is in the fabrication classes that utilize the shops. Classes must be sectioned to create manageable sizes for safety and to minimize damage to expensive equipment. ETEC 246 is a new course that will be introduced in 2011-12 that is replacing two courses that teach manual machining and foundry, forming and welding. The machining class has been a bottleneck course for several years. The organization of this new course will allow for larger class sizes at the expense of higher machine time per student.
- Breadth and Depth of Exposure to CAD/CAM Technology:There has been an ongoing discussion within the MET's Industrial Advisory Committee (IAC) about the depth of exposure to CAD versus breadth. The latter would mean exposing students to different CAD systems within the curriculum. As mentioned previously, CATIA is the system of use throughout the required courses. Students do have the option to work with other systems (SolidWorks, Pro-Engineer, Rhino) either through electives (ETEC 312 Rhino), independent studies or in their senior project. However, it is not a requirement that they do. The predominant sentiment within the IAC is that depth of exposure is preferable. The experience of many of these members is that a student skilled in one system can relatively easily transition to another with little or no formal training. There are of coarse other reasons to have additional CAD systems used in the required curriculum. One being that it helps develop and maintain the expertise of the faculty. Opportunities to include a second CAD system in a manner that does not excessively dilute the depth of instruction are under consideration. One would be to use SolidWorks or Pro-Engineer in ETEC 361 where advanced assembly design and kinematics is taught. Some of this content would be lost introducing students to the system at the beginning.
- Providing Industrial Experience: No formal co-op experience is available for students pursuing an ET degree at WWU. Thus, pre-graduation industrial experience can only be obtained through summer internships, part time employment and through industrial sponsored senior projects. The latter was not a requirement for the IT-CAD/CAM program. Its introduction in the new MET-CAD/CAM option offers a new opportunity for students in this program to get some real world experience before graduation. Senior project is divided into a two credit project definition phase followed by a four credit implementation phase taken in consecutive terms. An ideal scenario is for a student to work on an industry

sponsored project completing the project definition phase in the Spring term, work as an intern for the company over the summer and then complete the implementation phase in the Fall term. Being at the company over the summer allows the student to deepen their understanding of the problem and solidify contacts with experts there who can help them answer questions as the solution is implemented. Unfortunately this only works for a small portion of the students. Internships do not always accompany projects (more so these days) and students can start with their definition phase any term of the year. Regardless, the senior project experience is a new mechanism that will help to raise the quality of CAD/CAM graduates from WWU.

- Interdisciplinary Opportunities: The mix of programs in WWU's ET department by itself offers significant opportunities for synergy across technology disciplines. CAD/CAM students for instance take classes with students studying Plastics Engineering Technology to develop skills in plastic processing, product and injection mold design and composites design and fabrication. A cluster of electives have been identified to support this that supplement required courses (e.g. ETEC 335) already in the curriculum. They can also take classes with Industrial Design students and learn more on the styling and aesthetics in product design. CAD/CAM students also participate in team projects run by the department's Vehicle Design IT program e.g. FSAE and Baja. Through this they learn how to apply their modeling skills in this area.

  In addition to the above, the technical elective options support students taking a cluster of courses from the Manufacturing and Supply Chain Management (MSCM) major in the department of Decision Sciences. Since CAD data management is a critical need particular where this data must be securely distributed over a large supply chain, these electives help develop a technologist who understands and is better suited to global design and manufacturing. These electives can also be counted towards a minor in MSCM which helps to formalize credentials in this area. A similar opportunity exists with technical electives in mathematics. Together with a good GPA in the CAD/CAM major this opens the door to graduate studies at engineering schools. These can also be taken as part of a minor in Mathematics.

  Consideration is also been given to support interdisciplinary study with Computer Science. An option already exists for CS students to complete a minor in Electronics Technology. This is largely a hardware focus. A minor in MET that focused on CAD/CAM software tools could help give these CS students an advantage in finding employment with these software developers. The opposite (a CAD/CAM major doing a CS minor) is already possible and is encouraged in those students who show aptitude and interest in programming. This would increase their career options with larger companies that customize or augment their CAD/CAM software in-house.

The Next Step: A Stand Alone Program?

As mentioned previously, this approach of creating an option to develop a new, ABET accredited, stand-alone program has been practiced in the past by the ET department. Whether or not this will materialize with the CAD/CAM option depends on a number of factors:

- Interest in the Program: Given the size of other programs in the department, a senior class of between 15 and 20 students would support a stand-alone program. The initial interest in the new CAD/CAM option is encouraging. Twenty majors have declared since its introduction at

the beginning of the Fall 2010 term. It remains to be seen if this number translates into sustained senior classes of the required size. The backdrop of the current economy must also be considered when making this assessment. Are increases in interest in technology programs permanent or are they temporary with possible softening when hiring picks up in other areas?

- Employment Opportunities for Graduates: As already mentioned, CAD/CAM graduates have had reasonably good success finding jobs in their field after graduation. This should not change with the new option. Given the MET label there are companies that may hire CAD/CAM graduates with an eye to getting two skill sets in the one person. This would certainly be true if the CAD/CAM student in question took electives in automation. However, this would not be a true increase in opportunity but rather a re-distribution within a broader candidate pool. One thing to look for would be increased employment of CAD/CAM graduates at companies that use ABET accreditation as a hiring criteria (e.g. Boeing). As with the first point, consideration must be given to other factors one being the growing outsourcing of CAD jobs to specialists in other countries. This is part of the continuing erosion of the job pyramid that started with manufacturing jobs in the 80's and 90's. CAD/CAM graduates will increasingly have to compete with skilled and lower paid workers from countries like China, India and the developing world.
- An Expansive Curriculum: A stand-alone program will need to have opportunities to expand the curriculum to allow specialization. The current curriculum through the proposed technical electives already to some extent captures alternatives. However, there is room for additional courses that would both compliment and supplement the current experience. These would be in the following areas:
  - *Product Lifecycle Management (PLM)*: Exposure to the setup and use of a Product Data Management system would be a major component.
  - *Finite Element Analysis:* This would expand the introduction given in the Strengths of Materials course. It would include composite materials to support activities in the PET program.
  - *Factory Simulation:* CAD/CAM students would benefit from both 3D and discrete event simulation for cells and lines.
  - *5-axis NC Programming and Simulation:* Not currently offered due to lack of suitable equipment. Many regional aerospace and ship building companies use this technology.
  - *Reverse Engineering and Inspection:* This would be a focused exposure to laser, optical and contact digitizing technologies.
  - *Computer-Aided Tolerance Analysis:* This could be integrated with the previous topic or by including a focused study of GDT by itself.
  - *Machine Design:* A CAD approach would be adopted that integrates modeling with design and integration of machine elements. A course already exists that can be adapted to meet this goal.
  - *Dynamic Simulation:* A focus on vehicle dynamics would also make this an option for the Vehicle Design program. A course already exists that can be adapted to meet this goal.
- Availability of Resources: This is probably the greatest impediment to creating a stand-alone program. It involves both facility and personnel constraints. Most lab intensive and shop based courses offered by the ET department are currently over subscribed. Adjustments have had to be made in recent years to remove a number of bottlenecks. Still several of the technical elective options listed at the end of this paper are difficult to get into for non-

majors. A high demand CAD/CAM program would likely require larger labs which in turn would necessitate building expansion.

Currently a single faculty is responsible for coordinating the CAD/CAM option including teaching all advanced CAD courses. At least one additional full time instructor would be needed for a stand-alone program assuming that the CAM instruction will continue to be shared with the MET program. Both this and building expansion have been discussed. These are unlikely to bear fruit until the current state budget improves.

Conclusions

In summary, this paper presents efforts at WWU's ET department to develop an ABET accredited program for the CAD/CAM discipline. This has resulted in a recently introduced CAD/CAM option as part of an existing Manufacturing Engineering Program. This option currently has 20 newly declared majors. The new curriculum encapsulates CAD and CAM courses that formed the core of an IT program which the new option replaces. It adds to this more stringent Math and Science requirements and exposure to basic MET content. A flexible elective structure provides students with several options to tailor their degree. A senior project requirement helps in integrating knowledge and skills and offers the opportunity to gain practical experience by working on an industrial sponsored problem before graduation. This effort has the potential to lead to a stand-alone CAD/CAM program. A decision to do this would depend on the success of the option as determined by sustainability in the number of graduating majors, employment opportunities and the availability of new facility and personnel resources.

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MANUFACTURING ENGINEERING TECHNOLOGY – CAD/CAM OPTION
Approved Technical Electives

Four technical electives totaling 15 credits are required for the MET-CAD/CAM option.

	Number	Course Name	Credits	
1	ETEC 312	Industrial Design CAD Skills	4	[1]
2	ETEC 334	Reinforced Plastics/Composites	5	[2]
3	ETEC 338	Injection Molding	4	[2]
4	ETEC 352	Electronics for Engineering Tech. II	4	[3]
5	ETEC 354	Electronics for Engineering Tech. III	4	[3]
6	ETEC 397	(when relevant)	2 to 4	
7	ETEC 420	Manufacturing Automation and Robotics	4	[3]
8	ETEC 425	Machine Design	4	
9	ETEC 428	Advanced Manufacturing Lab	3	
10	ETEC 429	Directed Research in Manufacturing	3	
11	ETEC 426	Advanced CNC (additional versions)	3	
		a. Surfacing and Contours		
		b. Mill/Turn		
		c. Hi-Speed Machining		
		d. EDM		
12	ETEC 431	Plastics Product Design	3	[2]
13	ETEC 434	Advanced Composites	3	[2]
14	ETEC 444	Data Analysis and Design of Experiments	4	[3]
15	ETEC 497	(when relevant)	2 to 4	
16	OPS 460	Designing and Improving OPS	4	[3,4]
17	OPS 463	Enterprise Resource Planning Sys.	4	[4]
18	OPS 466	Supply Chain Management	4	[4]
19	MATH 204	Elementary Linear Algebra	4	[5,6]
20	MATH 207	Mathematical Computing	3	[5,6]
21	MATH 224	Multivariable Calculus and Geometry	5	[5,6]
22	MATH 331	Ordinary Differential Equations	4	[6]

1. ETEC 312 is highly recommended to broaden exposure to the use of different CAD systems.
2. This cluster of electives deepens a CAD/CAM major's exposure to plastics product design and processing.
3. This cluster of electives deepens a CAD/CAM major's exposure to manufacturing automation. By taking these electives a major completes similar program course content to the core Manufacturing Engineering Technology program.
4. This cluster of electives deepens a CAD/CAM major's exposure to business and manufacturing operations management.
5. Only one 200 level course can be counted as an elective.
6. Recommended math classes for majors wishing to deepen their analytical background for graduate studies.
7. Majors may also complete up to 4 elective credits through advisement. The work in question must demonstrate significant use of CAD/CAM technology. Pre-approval from the program advisor is recommended.