Virtual Simulation Curriculum Integration

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Abstract

Manufacturing simulation is being used extensively to model, analyze, and optimize complex manufacturing operations by many major corporations, including Boeing, Lockheed-Martin, Daimler-Chrysler and Toyota. Companies are utilizing these advanced 3D digital manufacturing tools as a component of their product life-cycle management. In many cases a simulation is mandatory prior to any significant new operation, project or process implementation. Manufacturing technologists and engineers will increasingly need familiarity with these tools and their applications. This becomes even more significant as manufacturing engineering programs evolve to satisfy the increasing demand for engineers to design and implement continuously improving industrial systems and programs. At Ohio Northern University (ONU) this technology is being taught as virtual simulation (VS). This paper explains how VS has been integrated into our curriculum, and has established effective partnerships with local manufacturing companies.

Introduction

Ohio Northern University is in the seventh year of a curriculum utilizing advanced industrial computer simulation software. The virtual simulation classes are offered in a sequence of three quarters, providing four credits per quarter. Students learn specific simulation applications from tutorials and online course materials. Teams of students work with local companies to create simulation models of actual manufacturing operations. Recent projects included work with major automotive original equipment manufacturers (OEMs) and suppliers, along with a major defense industry company. Each team prepares PowerPoint materials which are presented to representatives of the company. This presentation includes videos of the simulation, analysis of the operation, and basic suggestions for improvement.

The simulation applications used in these industrial projects include robotic workcell processing, ergonomics analysis, and discrete event materials/process flow studies. This curriculum has provided an opportunity for integration of several technologies and manufacturing management aspects into an application-based environment, including 3-D CAD modelling, robotics, and production system design. Students gain skills and experience in teamwork, project planning, problem solving, and formal multi-media presentations in company environments. Benefits include exposure to in-plant manufacturing operations, and the opportunity to personally deal with company representatives. Current students have obtained coop/internship positions, and graduates are finding simulation jobs in the fields of manufacturing and applications engineering.

Program Background

Ohio Northern University (ONU) is a private, comprehensive, United Methodist affiliated, liberal arts university with approximately 3300 students. The ONU Department of Technological Studies is in the College of Arts and Sciences, and prepares students for careers in professional, technical fields throughout industry and education. Graduates of this program are ideally suited for advancement into management and leadership positions in industrial organizations. Technology BS degree concentrations include advanced manufacturing, construction operations, multimedia design, design analysis, and technology education.

Students who follow the industrial track for technology with the Advanced Manufacturing concentration (which includes virtual simulation) are required to take the following core courses:

ECCS 164 Programming I
or CS 133 Visual Basic
Tech 000 Orientation
Tech 110 Introduction to Technology
Tech 120 Introduction to Computer Assisted Drafting
TECH 130 Metallic Materials & Processes 1
TECH 140 Microcomputer Applications in Technology
TECH 221 Computer Assisted Construction Design
TECH 321 Basics of Virtual Simulation
TECH 322 Virtual Simulation of Systems
TECH 223 Computer Assisted Product Design
TECH 230 Metallic Materials & Processes 2
TECH 232 Product Manufacturing
TECH 240 Intro. to Communication Technology
TECH 261 Fundamentals of Electricity/Electronics
TECH 294 Sophomore Seminar in Technology
TECH 332 CAD/CAM and Industrial Robotics
TECH 335 Manufacturing Automation Systems
TECH 342 Multimedia Design & Dev
TECH 350 Construction Technology
TECH 362 Digital Electronics: Concepts and Applications
TECH 412 Manufacturing Management
TECH 421 Solid Modeling for Design
TECH 423 Virtual Simulation Production & Management
TECH 430 Non-metallic Materials & Processes
TECH 435 Advanced Robotics (2 times)
TECH 460 Energy and Transportation
TECH 470 Quality Control and Work Measurement
TECH 494 Senior Seminar
TECH 495 Senior Project in Technology
TECH 496 Tour of American Industries

Suggested Electives:
TECH 484 Internship or
TECH 380 Professional Practice (Co-op)

A grant from the Society of Manufacturing Engineers in 1997 permitted the offering of virtual simulation (VS) as a senior capstone project for technology majors. By the summer of 1999, simulation internships had placed 12 of 17 students after running full-scale simulation classes [1]. Internship placements included NASA-Johnson Space Center, a Navistar truck plant, Deneb Robotics, DaimlerChrysler, and General Motors. By 2000 graduates with these skills received the following successful job placements: Applied Manufacturing Technologies (Systems Engineer); Argus & Associates (Simulation Engineer); Delphi Corp. (Simulation Engineer); Delmia (7 Interns); Detroit Central Tool (Robotics Simulator); General Motors (Simulation Engineer); and HRU Corp. (Project/Simulation Engineer). Based on these successes, and demand by students, the program expanded to a three quarter, four credits per quarter curriculum.

Simulation Curriculum Overview

The virtual simulation courses are taught in the Department of Technological Studies as a significant component of the Advanced Manufacturing concentration, and also as a Virtual Simulation Minor for students in other majors or colleges. This curriculum has provided an opportunity for integration of technology and manufacturing management aspects into an application-based environment.

The course materials use a combination of the tutorials, simulation exercises, application quizzes, and reality-based projects. The Technological Studies Department is currently utilizing the manufacturing simulation software offered by Delmia Corp. of Auburn Hills, MI, providing access to a variety of applications. The specific Delmia products used during 2004-2005 included IGRIP (robotics simulation), V5 DPM Envision Assembly (assembly/disassembly sequencing), V5 Human Modeling (ergonomics analysis), and QUEST (discrete event material and process flow analysis). An educational partnership with Delmia provides major software discounts, support, and training materials at costs that are practical for our program. For example, the annual quoted "commercial value" for the software licensing for the 2004-2005 year was nearly $6,000,000; the educational pricing provided these for under $20,000. Licensing is purchased each year on a per product, per seat basis, with the flexibility to select the specific applications needed. The software licensing may be loaded to specific machines, or onto a network server. An advantage of utilizing the Delmia suite of products is the common interfaces between their various applications. The parent company for Delmia is Dassault Systemes, which also owns the CATIA CAD/CAM product for parametric/solid modeling. Students utilizing the new Delmia V5 products gain proficiencies in this advanced CAD application during their course work.

Approximately 15-20 students enroll in the VS classes each year. The lab for these classes includes 10 high-end computer workstations equipped with dual monitors. As the students learn the various simulation applications they create independent projects to demonstrate and develop basic competencies. Student teams are formed to complete industrial company projects. The teams visit local manufacturing operations to observe processes, create simulations of the projects, and present the results at the company facility upon completion, including digital videos of the simulations and PowerPoint presentations. At the completion of the three VS courses, each student creates and presents a portfolio CD to the class summarizing all of their VS work.

This simulation curriculum provides the following benefits to our students and our program:

- Practical application of an advanced technology
- Generates Student Enthusiasm for Manufacturing
- Excellent Project Coordination Tool for Concurrent Engineering
- Teamwork Activities
- Project Planning
- Problem Solving
- Industrial Exposure
- Co-op/Internship Opportunities
- Job Placement Contacts
- CAD/CAM Systems Experience
- Application of other industrial technology applications and curricula

These other industrial technology applications include the following:

- 3-D solid modeling and data translation
- Robotics construction, kinematics, robot programming
- Ergonomics analysis
- Assembly sequencing
- Production layout & material flow optimization
- Formal multi-media presentations to industrial professionals.
- Creation of personal portfolio and CD

An additional advantage for the ONU program is the breadth of software available from a single supplier. The long learning curve for students to gain a reasonable degree of proficiency in creating and analyzing simulations would make it difficult if a variety of simulation applications with unique interfaces and operating systems were used. Dassault Systemes has creates a comprehensive suite of digital manufacturing software, including Delmia for manufacturing simulation, CATIA for CAD/CAM, and other applications for product life-cycle management. The variety of the Delmia applications, their consistency in user interface, and the compatibility between the applications maximize the opportunity for students to learn the process and capabilities of simulation analysis. In a sense, Dassault Systemes is creating a "Microsoft of CAD/CAM" (Nutter) with this standardization in the CATIA environment.

The extensive use of this specific simulation software by major companies in our geographical region (Honda, DaimlerChrysler, General Dynamics, and Toyota), and significant opportunities for internships, co-ops and jobs using this software at automotive OEMs and major defense industries provide an additional incentive.

Specific Simulation Coursework

To illustrate the ONU application of this curriculum, the following are the catalog course descriptions of the three VS courses, followed by comments on the teaching methods utilized.

TECH 321 - Basics of Virtual Simulation: "Development of basic skills to create computer simulations of components, equipment, and processes using advanced industrial software. Includes user interface; file configurations and networks; creating parts, devices and workcells; CAD geometry importing and exporting; motion kinematics; graphical simulation language programming; robotic workcell creation; and off-line robotic programming and operation."

Using Delmia IGRIP robotics simulation software, students immediately follow a short tutorial to create a 3D model their own hand, apply motion control kinematics and write a basic program. Students then use robotics libraries and the Delmia software to work through distance learning tutorials and videos provided by Immersive Engineering (Reference "Distance Learning Component" section for additional information). An online quiz for each chapter and a final exam verifies student comprehension, and exercises are submitted electronically to verify proficiencies. The final tutorial includes creation and generation of an off-line robotics program, which can be sent to a working robot in another location. All students work independently on their assignments, but frequently assist one another to overcome any problems they encounter.

Approximately midway through the ten-week quarter the students are split into teams of three to five persons for assignment to a company project. Based on individual preferences or company restrictions (e.g.; US citizenship) the project is designated and arrangements made for a plant visit. The team observes the plant operations, discuss the issues and company expectations, gather relevant data and information, and begin creation of the simulation. Additional plant visits and company communications are the responsibility of the students. A Gantt chart from Microsoft Project is submitted weekly, and project progress is monitored by the professor. Technical support at Delmia is solicited for especially complex, unique or unusual applications, along with software issues. During the ninth week of the quarter, the team presents the results of the simulation and analysis to representatives of the company, along with basic suggestions. A comprehensive PowerPoint presentation of each student's work for the quarter, including video files of the project, is made to the class and submitted on a CD.

TECH 322 - Virtual Simulation of Systems: "Development of in-depth virtual simulations of discrete events provided by industrial and educational partners. Each student will utilize the newest generation of simulation applications based on the CATIA CAD/CAM system to produce simulations for advanced analysis of ergonomics and assembly sequencing in manufacturing environments. Team work and problem solving are required."

Students are introduced to new CATIA based applications through tutorials and training materials provided by Delmia and CATIA. Each student works independently to create a unique assembly sequence of a complex 3D CAD model using the V5 DPM Envision Assembly software, and then presents the results to the class.

The V5 Human Modeling ergonomics simulation curriculum is provided with Immersive Engineering tutorials, similar to those used in the previous course, along with Delmia materials. Each student then creates and presents a unique ergonomic simulation based on a fictitious industrial situation, with an emphasis on use of the ergonomic analysis tools. Student teams are again formed at the middle of the term and assigned to a company project as in the previous quarter, and a presentation is made to the company. PowerPoint presentations of all the coursework for the quarter and a final CD are submitted.

TECH 423 - Virtual Simulation-Production & Management: "Development of advanced virtual simulations of discrete events. Factory layouts and process flows are analyzed utilizing state-of-the-art simulation software and computer equipment. Focus on project management, analysis, and class presentations."

Quest tutorials from Delmia are used for the student training, with specific exercises at the end of each chapter that are submitted electronically for grading. Each student creates and presents a fictitious, complex manufacturing system utilizing most of the standard components of the software. The classes are divided into teams who again go into manufacturing companies and create a simulation of a specific operation or process. Team presentations and suggestions are presented to company officials.

Each student formally presents to the class a final comprehensive portfolio of their VS projects, for the full sequence of courses. These portfolios are intended to be suitable for submission to a perspective employer, and are turned in on a CD for a final exam grade.

Company Simulation Project Examples and Descriptions

Following are brief descriptions of sample simulation projects completed during the past two academic years.

Fall Quarter: IGRIP (robotics simulation)
A simulation was created at the Lima, OH, General Dynamics Joint Systems Manufacturing Center (JSMC). A proposed robotic cell for welding panels for a proposed military vehicle was evaluated for throughput, reach and workspace requirements. See Figure 1.

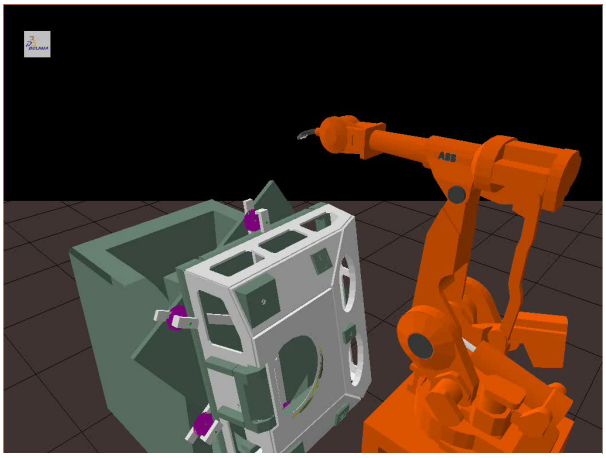

Figure 1: Robotic Welding Cell for Offline Programming

Two projects were completed simulating complex robotic spotwelding cells at the Honda automotive assembly plant in Marysville, OH. Existing and new equipment was being consolidated into significantly smaller workspace; clearances and accessibility for operators and parts handling were in question. Some of the equipment geometry was available from Honda's IGRIP models, with others created by the students in Pro-Engineer and imported into the simulation. All weld points and motions were programmed into the simulations and run to verify reaches and clearances. In one of the models the opportunity to eliminate a robot from the cell was identified by the students.

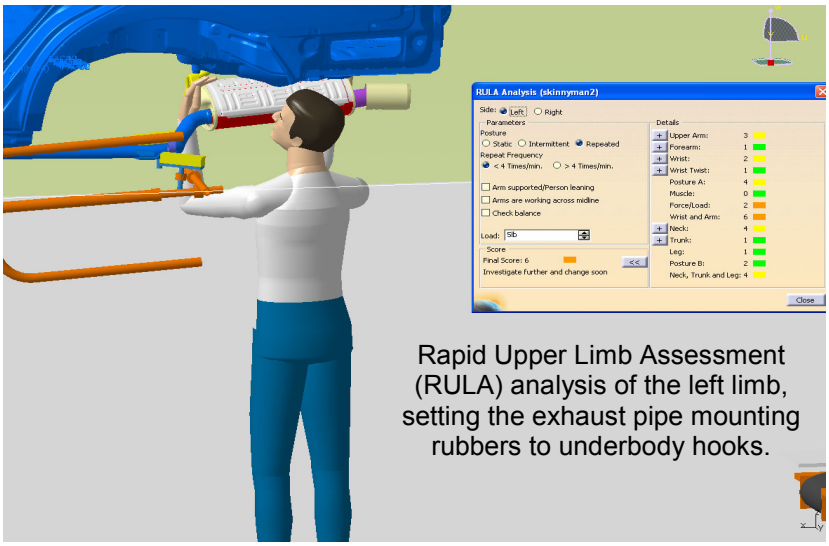

Figure 2: Ergonomic Analysis of Exhaust System Installation

Winter Quarter: V5 Human Solutions (ergonomics analysis)

An ergonomic analysis was completed for the installation of exhaust systems at a Honda automotive assembly plant. This study identified opportunities for fatigue and repetitive motion reduction.
See Figure 2

At a Ford engine plant two operations were video taped and simulated for ergonomic evaluation. Numerous postures and activities were rated and presented to the plant's safety committee. Some opportunities were identified and implemented immediately.

Spring Quarter: QUEST

Material/Process Flow Analysis

A simulation of miscellaneous machining operations for 104 different parts for a proposed military product was analyzed for throughput at the General Dynamics Joint Systems Manufacturing Center.

A study for the Ford Lima Engine Plant involved analysis of the machining and assembly operations on a new engine. The logistics and throughput for a cylinder head line was simulated with alternative material handling equipment, including lift trucks, AGVs and trailer trains. The visualization and recommendations of the simulation led to layout revisions for the installation currently in progress. See Figure 3.

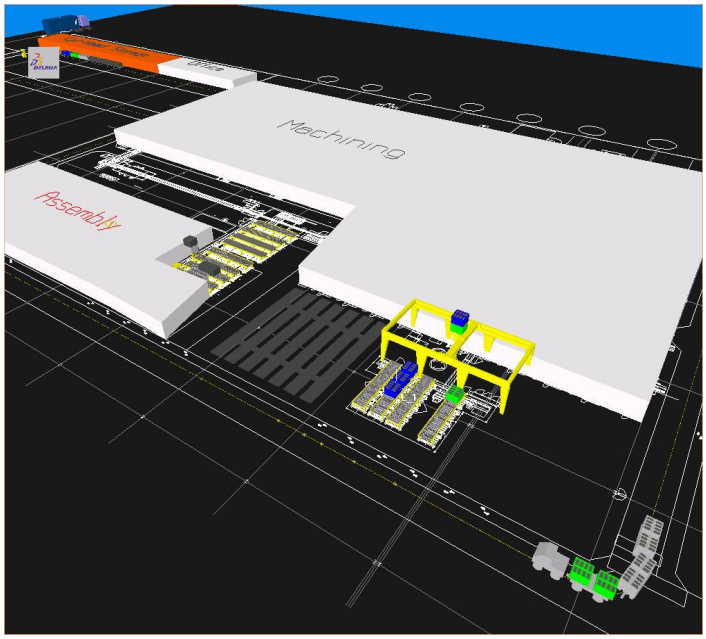

Figure 3: Discrete Event Material Flow with Trailer Train Delivery

Company Collaborations

The essential component in achieving successful company projects has been the establishment of a working relationship with an individual in the company who had the authority, interest and willingness to get involved. All companies have been very supportive and cooperative once the relationship was established, although it sometimes took patience, perseverance and repeated communications to achieve this cooperation. All contacts were very busy, but were receptive to the idea of providing the opportunity for students to gain first hand real world experience in dealing with manufacturing issues. The expectations of both parties and the deliverables were identified in the initial meeting between the students and the company representatives. When the projects were underway, and they found our needs were not very demanding, then the willingness to provide support and even encouragement grew. The companies have expressed high satisfaction with the results of the students work, with offers to provide future projects.

Successful Student Placements

The virtual simulation curriculum continues to provide graduates with excellent internship and job opportunities. Recent placements using VS included Dassault Systemes, Delmia, General Dynamics, Honda and Lockheed-Martin, along with several lesser knows companies.

Student Proficiencies

Students have been attracted by, and demonstrated enthusiasm, working with the highly visual computer-oriented nature of simulations, but have been impatient working through the details and complexity of the applications. A trainer of the IGRIP product at Delmia made the comment that it takes two years using the product in industrial applications to achieve 90% proficiency; this statement has been used to assure the students that they should not get frustrated, and that they should plan on extended usage to achieve high competency levels. Although basic proficiencies are desired, the more important objective is an understanding of how these tools can be used.

Issues and Comments

- Each year the specific applications for use are evaluated based on feedback from industrial users, Delmia sales discussions, and our budget constraints.
- Initial installation and LAN setup each year requires significant effort and information technology support due to issues with network licensing, network configuration modifications, and in providing flexibility for students working on various computers.
- Delmia technical support for software has been readily available and has been primarily needed due to efforts to make the simulations perform functions not specified in the tutorials. We originally experienced significant telephone bill expenses, but have reduced this by use of Internet support requests whenever possible.
- Software releases have been issued approximately every six months, requiring frequent evaluation of the new features and "bug" fixes in each release to determine the merits versus the risks. As much as possible we load the software available during the summer and avoid upgrades during the school year.
- Instructor training has been a significant issue due to the cost of training, the time commitment (3-5 days for each application), the number of different applications being used, and the frequent software upgrades.
- Students have demonstrated a failure to take the tutorials seriously unless given specific assignments or frequent testing. They would quickly go through the materials and then have difficulty when given an application problem. Multiple exercises are now assigned and submitted electronically to verify their progress.

Distance Learning Component

Currently a primary training tool for two of the simulation applications is distance learning tutorials from Immersive Engineering [3]. These tutorials are delivered in an internet-based digital manufacturing learning management system. A hybrid CD is provided which contains high quality video files for the tutorials. This CD is either run in the individual student's computer, or may be installed on a host computer within the school's LAN, eliminating the issue of slow response due to bandwidth restrictions. Students subscribe to the Immersive services individually through the internet; they are responsible for making the payments directly, preferably on-line from their personal checking account. Tutorial lessons are completed and quizzes taken which are scored and stored on a server at Immersive. The instructor has access to all student information, has control of student access to the system, and can revise or create new curriculum content and evaluation criteria remotely.

The Immersive materials and exercises have been instrumental in ramping up the student skill sets beyond the simple tasks of following mouse pick instructions, and have broadened the students understanding and comprehension of the applications to a higher level of engineering and managerial analysis. In addition to the specific Delmia simulation training materials the Immersive tutorials cover a significant amount of basic engineering and applications information. For example, students are exposed to explanations of various robot configurations, how to plan projects, and basic principles of ergonomics. Another Immersive service is the opportunity for "ProChat" interaction with a professional simulationist. During designated classes the instructor's computer is operated remotely by the Immersive professional who demonstrates features and functions of the software. An amplified speakerphone is used to permit dialog with the students and to answer questions. This process has enhanced the students' immersion into a virtual environment, and provides access to high level content and subject matter from other locations.

Additional distance learning opportunities are proceeding to provide a broader opportunity for students and companies off campus. Selected students have taken pilot courses using WebCT; it is anticipated that this format will be more widely available in the 2005-2006 school year.

Simulation Curriculum Opportunities

A study sponsored by the National Science Foundation identified "synthesis, modeling, and simulation for all manufacturing operations" as one of the top ten technology areas for meeting the challenges of manufacturing in the year 2020 [2]. The report also identifies significant opportunities in workforce education and training: "Educational and training methods that would enable workers to assimilate knowledge to improve their effectiveness are priority technologies."

"Research opportunities include the development of tools that are not language or culturally dependent; technologies that can capitalize on advances in the cognitive sciences; interactive techniques, **including simulation and virtual reality**; and learning modules that can be adapted and tailored to meet individualized educational needs."

Moderns manufacturing operations are increasingly dependent upon the synergies of employees, vendors and customers to achieve excellent performance. Creation of a common vision for project proposals and process improvements are essential for effective and efficient project and program implementations, and to stimulate best ideas and practices. The ability to communicate and capture ideas and proposals that can be shared across a broad cross section of personnel are integral components of concurrent engineering, cross-functional teams, lean manufacturing, and self-directed work teams. These are the mechanisms that have permitted Japanese and Asian companies to dominate in many industries, and which are being embraced by the most successful American manufacturers.

The original math based simulation applications of several years ago were primarily the domain of industrial and systems engineers for analysis and interpretation. The high visual nature of the newer object based simulations lends themselves particularly well to current management trends utilizing cross-functional teams and concurrent engineering. As illustrated in Figure 4, the use of the animation functionalities provides workers, technicians and management better understanding and conceptualization of new layouts and processes before they are built, permitting improved brainstorming and idea generation.

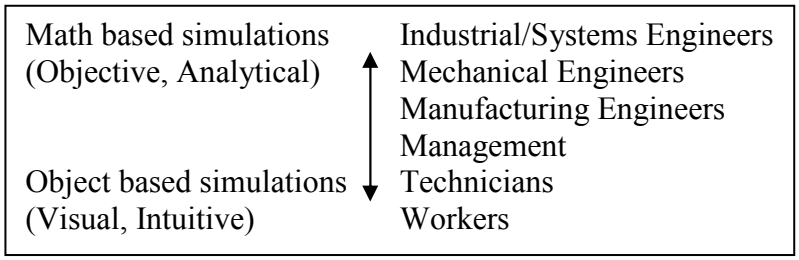

Figure 4: Simulation Spectrum of Comprehension.

At ONU additional simulation applications are planned or under evaluation for incorporation into the technology curriculum. These include Delmia's V5 DPM Powertrain, Process Engineer, and Workload Linebalance, along with other applications in demand by industry. Planning is also in progress for integration of the Delmia simulation applications into other Ohio Northern University courses, including PLC's and Industrial Robotics, CAD/CAM and Automation Systems, and Advanced Robotics and Automation.

The following VS opportunities are also under consideration:

- Summer technology camps for high school and middle school students.
- Commercial industrial training both on site and with distance learning.
- Creation of a Center for Advanced Manufacturing to integrate Technological Studies, the ONU College of Engineering, the College of Business Administration, and industrial companies in new partnerships.

Summary

Manufacturing companies are pushing the envelope to gain competitive advantages through rapid development of new products, processes and production systems in lean environments that emphasize continuous improvement. Companies are embracing digital manufacturing, product lifecycle management and simulation analysis as tools to achieve their goals. Boeing, General Motors, the United States military, and others are mandating that simulations of major projects be completed prior to implementation. Graduates of engineering and technology programs who have an understanding and ability to apply these tools will find many opportunities as our economy continues to grow.

During the 2004-2005 school year at Ohio Northern University the requests for graduates, co-ops and internships with simulation experience has significantly exceeded our supply of students. The virtual simulation program is a distinctive component of the ONU Department of Technological Studies, and is providing excellent opportunities for student field experiences and applications of advanced computer technologies. The curriculum provides the opportunity for real-world projects, internships and jobs for our students, and is providing modern industrial companies with effective management and manufacturing engineering professionals.

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Biography

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Professor Nutter is in his fifth year teaching industrial technology at Ohio Northern University, and has a BSIT and MBA from Ohio University. Principal courses taught include virtual simulation, manufacturing management, and quality assurance. He has 26 years of industrial experience, with the majority at Rockwell Automotive in manufacturing and industrial engineering. A Certified Manufacturing Engineer by the Society of Manufacturing Engineers, during 2005 he is serving SME as chairperson of the Student Relations Sub-Committee, is on a Youth Programs Task Force, and is faculty advisor for the Ohio Northern University student chapter.