

## **Creating an Engineering Enterprise Team Based on the SAE Clean Snowmobile Challenge**

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### Introduction

The Enterprise Program at Michigan Technological University was implemented in the fall semester 2000 as a response to the NSF sponsored Action Agenda Program encouraging engineering education reform. The following goals of the MTU Enterprise Program are addressed through both course work and project work:

- promotion of student based and life-long learning
- promotion of active, collaborative learning
- promotion of faculty as mentors
- integration of design, teamwork, communication, and problem-solving
- inclusion of cost, project management, and quality issues
- recognition of diverse learning styles and career objectives

The program consists of an innovative sixteen credit elective path; nine credits of course work and seven credits of project work, that combines traditional classroom learning with realistic engineering practice in a modern engineering curriculum. The course work is delivered in one credit modules and emphasizes communications, business, and teaming, as well as engineering topics. The project work is accomplished in student teams of 20-30 working on a significant engineering assignment. The engineering enterprises provide a major design experience for its team members and have a life span of multiple academic years. Sophomores hire into and graduating seniors retire from the Enterprise. The purpose of this paper is to show how one of the enterprises, the Clean Snowmobile Enterprise, has been implemented, how the design portion of the experience differs from a traditional senior design project, and the expected enhancements over the traditional design experience. A more specific overview of the Enterprise Program can be obtained by reading the paper entitled, "The Enterprise Program at Michigan Technological University", by M. R. Plichta and M. Raber, presented at the 2001 American Society for Engineering Education Annual Conference and Exposition.

### Clean Snowmobile Enterprise Background

The Clean Snowmobile Challenge (CSC) is a Society of Automotive Engineers (SAE) national collegiate design competition that was created by Dr. Lori Fussell and Bill Paddelford to address the concern of snowmobile use in environmentally sensitive areas. The goal of the competition is to significantly reduce noise and emissions from snowmobiles while maintaining current

performance levels and cost<sup>1</sup>. Teams are awarded points for design and performance categories. The CSC was selected to become an Engineering Enterprise to provide students with credit for their design work. In the past, students volunteered their time to be involved with specific collegiate competitions.

### Enterprise Implementation

The sixteen credit elective path is detailed in Figure 1.

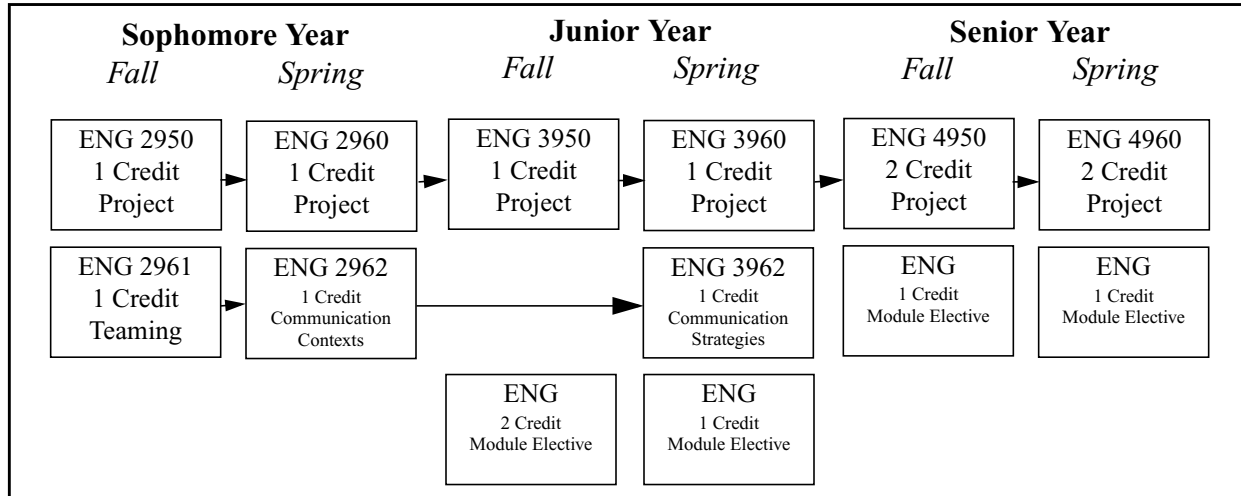


Figure 1. Enterprise implementation flow chart

Credits taken for the Enterprise replace fifteen traditional credits; three credits of general education, six credits of senior design, three credits of technical electives and three credits of free electives. Students who chose the Enterprise option graduate with one additional credit. Enterprise elective requirements can be satisfied through a diverse offering of modules. Topics include engineering ethics, economics, industrial health and safety, design for manufacturing and a variety of additional subject matters.

### Enterprise Structure and Operations

The Clean Snowmobile Enterprise design team of 20-30 students is divided into groups that are responsible for specific areas of the snowmobile, to ensure an effective learning experience. The specific groups consist of: Engine, Chassis, Technical Communications, Public Relations, and Finance. The organizational chart for the Clean Snowmobile Enterprise is shown in Figure 2. Each group has a leader who reports to an overall team leader. The faculty advisor interacts with the team at the executive board level.

The product development cycle of producing a cleaner and quieter snowmobile for use in National Parks includes conceptual design, analyze, fabricate, test and market the product at

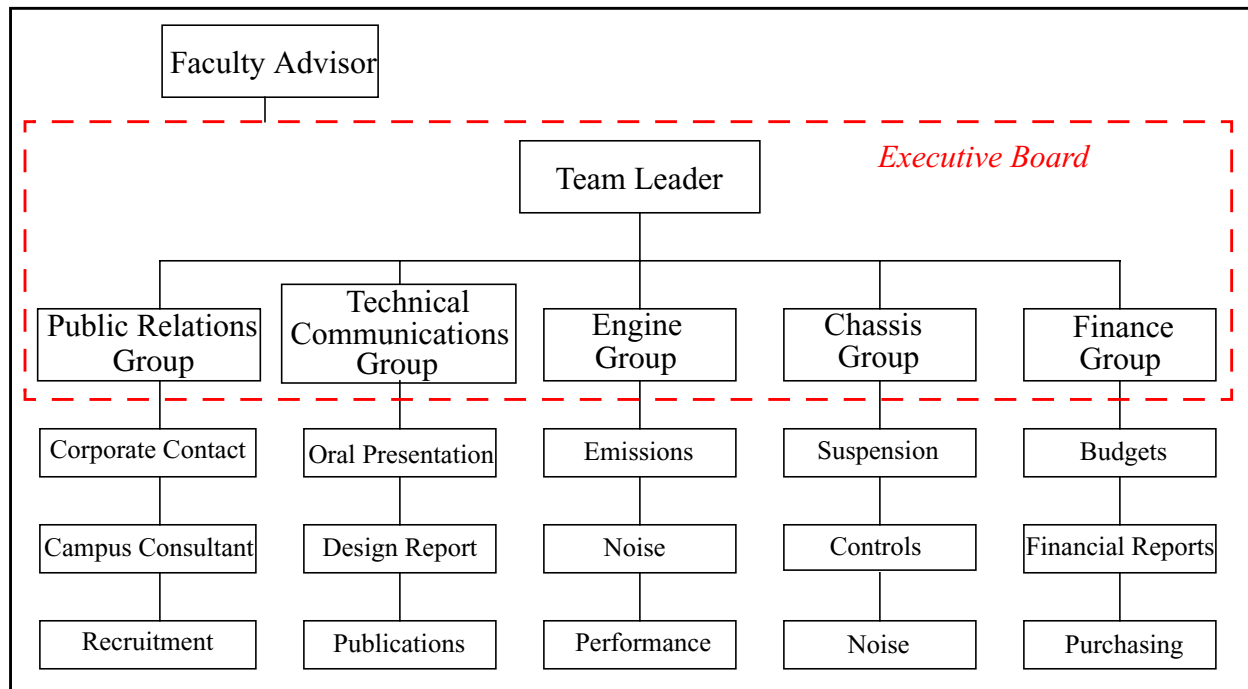


Figure 2. Organizational Chart for Clean Snowmobile Enterprise

competition. Team members design structural members, calculate durability expectations, utilize clean engine technology, and maintain vehicle performance. The prototype snowmobile must be fabricated for competition and it is at this stage of development that members realize they are designing and building a real vehicle and it is their design that is being produced. The completion of the prototype snowmobile leads to testing. Team members test their design to determine emissions and noise production levels, real-world performance and reliability. After sufficient testing of the vehicle, the team addresses design flaws and the snowmobile is prepared for final competition. Continuous design improvements lead to a refined snowmobile that eventually approaches a consumer-ready vehicle.

A key step in managing the team of 20-30 students is for each member to have a specific job assignment combined with a detailed Gantt chart. The group leaders are responsible for constructing individual assignments for team members, keeping their group on task and intervening when a difficult problem arises. An assignment may require a single person or up to five members. Three levels of Gantt charts exist in the Clean Snowmobile Enterprise. The overall Gantt chart, created by the team leader, involves major milestones and complete vehicle coordination. The group Gantt charts, created by each group leader, concentrates on the tasks of the engineering groups. The individual Gantt chart, created by the person(s) working on a job assignment, organizes the details of their specific task with a description of the semester goals. All three levels of Gantt charts are continuously reviewed and coordinated by the team leader, group leaders and faculty advisor.

Business operations are a significant part of the student effort in an Enterprise with budgets between \$25,000 to \$80,000 per year. Business majors participate in the Enterprises to help manage the financial responsibilities.

The Clean Snowmobile Enterprise has three distinct types of meetings. The Executive Board consists of the team leader, group leaders and the faculty advisor. The Board meets once a week to discuss budgets, group progress, Gantt charts, long-term goals and problem areas. A weekly team meeting allows all members to follow the project progress, review the overall and group Gantt charts and conduct team decisions. The third type of meeting within the Enterprise is the group meeting. Team members meet with their group leader to discuss engineering solutions and review both the individual and group Gantt charts. This type of meeting often includes work sessions on the snowmobile.

### Grading

Evaluation of individual team members is accomplished through multiple instruments. Twice a semester, product design reviews (PDR's) are conducted in which each team member participates. During the PDR, the student presents their project in detail, the progress they have made to date, their specific Gantt chart, and future work to be completed. The entire team is present during the PDR's and each member evaluates the presenter using a MTU Mechanical Engineering - Engineering Mechanics Department (ME-EM) assessment instrument.

Throughout the program each team member is also required to build a portfolio of their best work on the project. The portfolio is organized by educational objectives. The specific objectives that were considered pertinent to this Enterprise are<sup>2</sup>:

- ability to apply knowledge of mathematics, science, and engineering
- ability to design and conduct experiments, as well as to analyze and interpret data
- ability to design a system, component, or process to meet desired needs
- ability to function on multi-disciplinary teams
- ability to identify, formulate, and solve engineering problems
- understanding of professional and ethical responsibility
- ability to communicate effectively
- the broad education necessary to understand the impact of engineering solutions in a global and societal context
- recognition of the need for, and an ability to engage in life-long learning
- knowledge of contemporary issues
- ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
- ability to work professionally in both thermal and mechanical systems areas including the design and realization of such systems
- ability to apply project management skills to an engineering enterprise

At the end of each term, a performance evaluation of each member is conducted by the team leader, group leaders, and faculty advisor. The group leaders evaluate those members in their group and the team leader evaluates each of the group leaders. The faculty advisor evaluates the team leader and each of the portfolios and has the final responsibility for all grades.

The national SAE Clean Snowmobile Challenge competition is held in Jackson, Wyoming each March. The team is awarded points based on 1) achievement of performance criteria and 2) comparative performance to the other entrants. The final team score that is received at competition becomes part of the spring semester grade for each member. In addition to the final team competition score, each team member is graded on their contribution to the final written report. The competition score and written report contribution are used for grading only for the spring semester. The fall and spring semester grade percentage is provided in Table 1.

*Table 1: Grade Percentage for Fall and Spring Semester*

Semester	PDR 1	PDR 2	Portfolio	Performance Evaluation	Competition Score	Written Report
Fall	20%	20%	40%	20%	0%	0%
Spring	10%	5%	40%	10%	25%	10%

### Design Experience Comparison

Many of the educational goals that are addressed by the design experience in the Enterprise Program are shared with the traditional senior design project. Michigan Tech has decades of experience working on student design competition projects and can effectively compare and evaluate the design experience in the Enterprise to a traditional senior design project. Individual components that differ significantly are detailed in Table 2.

*Table 2: Design Comparison - Traditional versus Enterprise*

Senior Design Project	Enterprise Design Experience
two semesters during senior year	multi-year, sophomore through senior years
teams of five students	teams of 20-30 students
limited project expert knowledge	thorough understanding of project from multi-year exposure
no archival of knowledge	archival of expert knowledge
one job assignment	several job assignments
design part or subsystems	complete system design
modest exposure to business operations	full exposure to business operations
curriculum requirement	elective option within curriculum

The combination of project duration, team size, expert knowledge and complete system design impacts issues such as the breadth of engineering functions and complexity of the project that become feasible, team dynamics, and student-faculty interactions.

## Conclusions

The Enterprises have a life year-after-year, which allows students to develop expert knowledge that is retained and passed on to incoming members. All of the enterprise processes are expected to evolve to increasingly higher levels. This will allow not only for conceptual design, but give students a better chance at progressing to the other engineering functions such as prototyping, testing, and evolutionary design. Over a three year period, enterprise students have the opportunity to specialize in several job functions including leadership positions.

Enterprise teams tend to work truly on the system level. We think that this more closely matches the trend toward the complexity that faces industry today. It forces the student to think on a broader scale, and often requires the inclusion of societal and political issues in the design process. Enterprises that culminate in a national design competition provide the capstone experience in the engineering enterprise - taking the product to market. Benchmarking one's product against the competition is an important lesson for young engineers in a competitive environment.

The enterprise is an elective option that involves students that are often passionate about their work. A significant benefit of the program is that the students feel a strong sense of ownership of their work. They feel like engineers rather than students. They understand that they own their education and that they are developing professionally while in an educational environment.

## Bibliography

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Scott A. Miers is currently a doctoral student at Michigan Technological University. He received his B.S. in Mechanical Engineering from Michigan Tech in 1995. Before returning to graduate school, he spent two years in industry as a research engineer. In addition to research, Scott is actively involved in the Michigan Tech Clean Snowmobile Enterprise and has participated in an NSF teaching fellows program at a local high school.

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Carl L. Anderson is an Associate Professor of Mechanical Engineering at Michigan Technological University. Dr. Anderson received a B.S. degree in Mechanical Engineering from Michigan Tech in 1972, an M.S. degree from Stanford University in 1973 and a Ph.D. in Mechanical Engineering from the University of Wisconsin-Madison in 1980. He serves as a co-principal investigator on the NSF Action Agenda grant at MTU. He has been a faculty advisor for the SAE Student Branch including Project Advisor to SAE Mini Baja, Formula Car, FutureCar, and Clean Snowmobile. He has received the SAE Outstanding Faculty Advisor Award in 1993 and 1997 and the MTU Distinguished Service Award in 2000.

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