'Early Immersion': High school students participating in Engineering technology's Senior Design projects at Miami University

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I. INTRODUCTION

Grounded in liberal education concepts [1,2], senior design course pulls together various engineering concepts and skills towards a real-world problem. Emphasis is placed on teamwork, communication, economic and safety considerations and developing liasion with industrial partners. Students are encouraged to think critically, engage with others, understnad the various contexts and reflect on their actions throughout the project.[3-5]

At Miami University, the senior design project course is also used to establish bridges with local high schools by participating in FIRST robotics comeptition. Started in the year 2001, this course has been successful in collaborating with local high schools participating in the competition. The FIRST robotics competition [6] engages university students in a challenging 'design-build-and test' project, while working side by side with industrial engineers and high school students. Through the competition, university students complete a demanding engineering project and motivate a new cadre of students to follow their career footsteps.

After a brief description of FIRST competition, the paper oultlines the students'participation with high schools in the competition. This paper illustrates how liberal education principles are at work in the senior design course.[7]

II. FIRST ROBOTICS COMPETITION

Although the technical programs at American Universities continue to improve to maintain their world-wide recognition as the very best, the primary and secondary education systems do need considerable improvement. There is a growing gap between instructor expectation and the performance of these high school graduates. The report "Engineering Education in a changing world"[8] addresses *educational partnerships* as one of sixteen action items to direct the future of engineering education. As stated in the report, "*Each engineering college, with local industry, should partner with atleast one local on the K-12 level. The aim is to improve mathematics and science instruction, provide role models, and give students and teachers a greater inderstnding of engineering's role in society."*

One program that is promoting partnerships between industry/ universities/ K-12 schools is FIRST (For Inspiration and Recognition of Science and Technology). Since the year 2001, the FIRST Robotics Competition, an annual design challenge is being used as one of the projects for senior design capstone course. Miami University started to participate in the Robotics Competition through the senior design course with Northwest High School (2001 and 2002), and Lakota East High School (2003).

FIRST, a nonprofit organization founded in 1989 by inventor and entrepreneur Dean Kamen[6], inspires students to consider careers in engineering, technology, and science. The aim is to show students not only that the technological fields hold many varied opportunities for success and are accessible and rewarding, but also that the basic concepts of science, math, engineering, and invention are exciting and interesting.

Learning to plan and implement the entire design process can take a long time, but it is the most valuable lesson that is learned in FIRST Robotics Competition. In most of projects, engineers are challenged to put together different systems. FIRST Robotics provides an excellent opportunity to explore this. For example, students must analyze the rules of game and then agree on a realistic design concept to meet their goals. Then several systems, such as mechanical arm, electrical controls, and motors are assembled together following the constraints on weight and size.

III. ESSENTIAL ELEMENTS OF SENIOR DESIGN COURSE-

At Miami University, the senior design project assimilates engineering design, analysis, and liberal education concepts such as cost/benefit analysis, environmental issues, and ethics [4,5]. First developed in 1996 by the Department of Engineering Technology, the senior design course was later approved by the Liberal Education Council as a Capstone course. By focusing on the principles of liberal education at Miami, students learn to ask why they are designing a project, not just how to design it. The department has seen the liberal education component in ENT 497/498 as a valuable asset.

The senior design course spans two semesters as ENT 497 and ENT 498. The course embodies the application of the knowledge of senior Engineering Technology students in performing a major open-ended design project. Each group of students along with a faculty mentor work in design teams that utilize their combined expertise and skills to achieve a successful design.

The fundamental elements of the design process are considered in this course through continuous interaction with faculty and bi-weekly seminars by outside professionals. In this course, a variety of methods is offered to the students to enable them to develop their designs. As appropriate, seminars on topics relevant to the projects and design are conducted by the faculty, students, and guest speakers from industry and other institutions.

Along with guest speaker's seminars, the students and the faculty meet regularly. In each of these meetings, students generate minutes that describe the discussions, activities to be conducted in the future, progress to date, and persons responsible for future tasks.

The design projects include the establishment of objectives and criteria, synthesis, analysis, and evaluation. In all designs, students will consider realistic constraints, such as economic factors, marketability, human factors, safety, reliability, aesthetics, ethics, and social impacts.

The projects offered in this course are chosen from real-world problems. This is intended to enable students to recognize current needs and trends in industry and society. The first part of the project (ENT 497) deals with feasibility studies or proposals. The second part (ENT 498) is the actual implementation, testing, and production or simulation of the prototype. Because design is an iterative process, the students may find it necessary to adjust their proposals from that in ENT 497.

At the end of the second part (ENT 498), the students are required to give a demonstration of their developed design. This is done by using computer simulation or by physical testing. The format for the final report is similar to that of ENT 497 but contains more information about the final design: analysis, mathematical model, cost, and operational procedures.

In general, students are graded and evaluated according to their performance in four areas:

1) Finishing the proposed design,
2) Reports, which include final report, minutes, and other progress reports;
3) Participation, which includes meeting attendance, discussions, active involvement, and leadership in carrying on one's responsibility;
4) Midterm and final presentations.

It should be noted that the students are working in groups to emphasize the importance of teamwork in real life situations. Each group is responsible for dividing the different tasks among its members, writing reports, and presentations. Individuals within a group may receive different grades. Grades are determined by regular evaluations taken during the semester by the instructor and by the students for each individual. While the student input will be given considerable consideration, in the event of conflicting opinions or other such problems, the ultimate grade determination will be by the instructor.

In order to foster the consideration of social context and other non-technical issues when designing, building, and implanting engineering projects, liberal education concepts are introduced into the senior design course. These are ‘critical thinking’, ‘understanding contexts’, 'engaging with other learners’ and ‘reflecting and acting’[1].

- Critical thinking: Critical thinking is to involve imagination, intuition, reasoning, and evaluation in such a way to analyze systematically and solve complex problems[1].
- Understanding Contexts: The relevance of the problem and the solutions to the society, environment, and the well being of people is as important as the problem and the proposed solution. Knowledge of the conceptual framework and character of the society are essential inputs. [1]
- Engaging with Others: Only through open and honest exchange of ideas with piers and teachers and colleagues does one accomplish a balanced solution. Active listening, exchange of ideas, reevaluation of established views and critique through actively seeking other’s

opinions are corner stones to achieve a proper result.[1]

- Reflecting And Acting: Practice decision-making and evaluation of the repercussions thoughtfully. The idea is to enhance personal moral commitment, enrich ethical understanding, and strengthen civic participation.[1]

IV. Robotics Competition as Senior Design project

There is an excellent fit in the basic requirements of senior design course and the essential elements of the Robotics Competition. FIRST schedule parallels the time line for senior design projects. FIRST competition brings professionals and young people together in teams to solve an engineering design problem in an intense and competitive way. Students of the senior design course- by participating in the FIRST robotics competition are able to fulfill the basic requirements in terms of critical thinking, understanding contexts, engaging with others and reflecting and acting.

After the kick-off meeting, the design process begins immediately with the construction of the playing field and scoring apparatus. The planning of the project starts with brainstorming game strategy, general mock-ups and design testing. Once a design is completed to satisfaction, building of the robot chassis begins and is followed by the addition of drive systems, scoring mechanisms, control systems, and wiring.

IV.1. CRITICAL THINKING

All senior design projects require a component of engineering analysis. Critical thinking in engineering technology is most often constitutes the analysis, design, implementation and project management. In most senior design projects, the principles learned in prior courses are used as a guide for conceptualizing a complex project, designing the system using engineering analysis to mathematically model the system, then building it. Critical thinking skills are used in planning, analyzing problems, formulating alternative solutions, implementing solutions, and documenting the results. [11,12].

The typical robotics competition involves the use of motors, guidance controls, pneumatics, and mechanical forces. The guidance system consists of a transmitter and receiver module. The foundation for the design and building of the robot's electrical system is based on courses such as circuits analysis, introduction to electrical engineering, industrial electronics. Computerized instrumentation and feedback control, Electro-mechanical control systems will be used as possible reference for programming of the guidance system and control of peripheral devices. A simple programming language such as "BASIC" is used. Last year's project attempted to apply principles from ENT 412 Neural networks and fuzzy logic but was unsuccessful. Statics and Dynamics courses are refereed to for calculations involving the mechanical operations of the robot. (i.e. center of gravity, center of gyration, friction forces, motor torque, velocities, potential & kinetic energies, etc.). Applied fluid mechanics course is used as a reference for the application of pneumatics.

As in the case of all senior design projects, the robotics competition contains a significant aspect of project management. Even before officially registered in to the competition, students define several key areas relevant to the smooth operation of project. These are:

- Establishing Objectives
- Project Overview
- Administration
- Fundraising Issues
- Company Contacts
- Sponsorships
- Developing Group Responsibilities
- Mentoring Roles
- Working with High school students-issues

By identifying these items and developing each one, students are gaining valuable experience in project management.

The students understand that they have only six weeks to design, build and ship the robot. Students make fall and winter schedules. All student team members must attend these sessions. Adults are encouraged to attend any meeting or activity. An outline of a typical FIRST season schedule and major tasks is shown in Table-1.

During the “Build Season”, (between Kickoff (1/4) and Robot Ship (2/18)) team members will be working in the “Shop” at times. On Thursday evenings, “all-team” meetings are held to share information about progress of the project, fund raising, and other issues. Typically, parents of team members volunteer to provide dinner. During the “Competition Season” (between 2/25 and Nationals), team members may be working in the School Lab at these times.

IV.2. ENGAGING WITH OTHERS

In typical senior design projects, each group has two or three students in them. Students are required to meet at least once a week outside of class, and keep the minutes in a journal. The instructor regularly reviews the journal to see how well the students are working together. If there is a communication problem, the instructor resolves it quickly, rather than let it fester throughout the course.

In FIRST Robotic competition, teamwork and interaction with the team members is most important. When the students start their senior design course, they need to organize the team and prepare for the season ahead. There are many tasks to be accomplished. The important thing is to identify the team, establish team concepts, and develop partnerships.

IV.2.1. Team Organizing: As shown in Table-2, the participants of the Robotics competition are grouped into different levels- Miami University students, Lakota High School Students, Sponsors (Proctor and Gamble) and Parents and Retired Engineers in the community. The senior students of Miami University, the educational partner, are focused on conducting their senior design project while mentoring the high school students and learning to work in a team environment with the experts in the field as well as understanding the financial side of the project.

The High School students are key part of the FIRST team.

In Robotics competition, numerous work teams are put together from the different levels of participants based on their weaknesses and strengths. This is to focus on specific tasks of the project such as logistics, public relations, machining, and, computer support, including animation and design. High school students learn design, leadership, marketing, publications, public relations, fabrication, CAD, scouting, and animation projects.

TABLE-1 THE PLAN

September-October:	Organize team	
October-December:	Facilitate fundraising and team building	
January-February:	Obtain game rules, design, build, and ship robot	
March-April:	Attend competitions	
Fall Schedule	November 7	Information Meeting 2:45 – 3:30
	November 14	Applications Due 3:00
	November 18- 20	Student Interviews
	November 21	Team selection announced – Morning Announcements
	Training	Training times will be from 2:30 – 4:30
	December 4	Team building session / Safety / Shop tour
	December 5	Team training – Brainstorming / Ideation
	December 11	Team training – Prototyping / Mock-up
	December 12	Team training – Hand Tools / Power Tools
	December 18	Team training – Machining / Mechanics
	December 19	Team training – Design / CAD / Animation
Winter/Spring Schedule	1/4	Sat 9:00 Kickoff
	1/5	Sun 1:00 Field Construction
	1/6	Mon 2:30 Final Field Construction
	1/6	Mon 4:00 Team Kick-off
	1/7	Tue 4:00 Game Strategy
	1/8- 1/9	Wed-Thu 4:00 Ideation
	1/13- 1/16	Mon-Wed 4:00 Prototyping
	1/16	Thu 4:00 Prototype presentations
	1/20-1/22	Mon-wed 10:00 Design - Manufacturing
	1/23	Thu 4:00 All team re-connect
	1/27-1/29	Mon-wed 4:00 Manufacturing
	1/30	Thu 4:00 All Team
	2/3- 2/4	Mon-Tue 4:00 Electrical / Wiring
	2/5	Wed 4:00 Programming Complete
	2/6	Thu 4:00 All team
	2/10- 2/12	Mon-wed 4:00 Testing – Debug Machine
	2/13	Thu 4:00 Final All team w/ robot
	2/14- 2/15	Fri-Sat 10:00 Driving Practice
	2/17	Mon 10:00 Crate Build
	2/18	Tue 10:00 Assembly (school presentation)
	2/18	Tue 4:00 SHIP ROBOT!
	3/5 – 3/8	Buckeye Regional Competition

Build Season		**Competition Season**	
Monday-Thursday:	2:30 – 7:00	Monday:	Off
Thursday	All-team evening meeting	Tuesday:	2:30-4:30
Friday:	Off	Wednesday	2:30-4:30

Saturday:	9:00-4:00 (if needed)	Thursday &Friday	Off
Sunday:	12:30-4:30 (if needed)	Saturday:	As needed
		Sunday:	Off

TABLE-2: Members of FIRST team

Lakota Local School	Miami University	SPONSORS- P & G	Parents & Retired Engineers
3 teachers	Division Chair, Program Chair, Course Advisor	Lead - Mechanics	
25-30 students 10 –seniors 10 juniors 10 sophomores	3- students	1-Mechanical Design (Assembly) 1-Mechanical Design (Fabrication) 3-Mechanical Design 1-Administration 1-Electrical /Controls	7 Adults

IV.2.2. Support for the Teams: The team has several partnerships that will enable multiple levels of support. Miami University is the educational partner for this team. The community partnership is provided by the 'Corporate Engineering Technology Labs' of Proctor and Gamble**.** In addition, the team is developing new partnerships with high tech companies in the community.

Support for the team is provided in various ways. The participating High School provides travel costs for teachers to attend the different contests. Sponsors like Proctor and Gamble not only support financially, but also supply engineering, mentoring, materials, and tools. Miami University takes care of the travel costs of their students. Miami University also hosts a design presentation by the senior students to attract further funding and support from the local industries.
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IV.3. UNDERSTANDING CONTEXTS

In performing the senior design course, understanding contexts is a vital liberal education element. Rather than rush to build the project, students participate in literature research and brainstorming sessions in the first part of the course. This helps the students to consider all aspects of the project. Feasibility studies help students envision the effect their product will have once it is designed and produced.

The central focus of the projects is engineering design; so all projects are required to have a significant component of engineering analysis. Students generally find an industry sponsor to fund and mentor the project. This way, students gain a perspective outside the classroom.

Understanding contexts includes other factors besides mathematical analysis. Students are required to include in their design such topics as cost/benefit analysis, safety, ethics, environmental issues, and aesthetics. The company sponsoring the project also mandates these components. Students see the context that the project will be used in, not just engineering analysis.

In the FIRST competition, one of the first tasks that the student groups perform is to examine the kit and evaluate what extra materials, and accessories might be required. These materials were referenced through the Internet, and through contest supplier data sheets. One of the competition guidelines specifies maximum machine weight. The contest will not only test the machines ability to perform functions required but also require it to perform the specified task against other machines and time. This competition calls for lightweight materials being able to support moderate loads and the ability to withstand forceful impacts. Two types of materials are typically chosen- aluminum 6061-T6 and polycarbonate lexan D638. Besides being lightweight, the polycarbonate lexan has the ability to stay intact during impact with other robots on the field. Both aluminum and the polycarbonate are easily machinable and good materials for assembly. Lighter machines require lesser energy in terms of motor drive and the requirement of lower torque and speed ratings. For the drive system to mobilize the machine, Bosch Drill Motor, with 300 rpm (low gear) and a stall torque of 29 N-m, was chosen.

IV.3.1. Budget: Budgeting and analyzing financial aspects of the projects is a vital part of the Senior Design Course and the robotics competition. Following is the FIRST competition budget requirement for 2003.

TABLE-2: BUDGET		
ESTIMATED	Regional	National
Entry fee 1st event	$5,000	
Entry Fee 2nd event		$4,000
Kick-off	$200	
Playing field	$400	
Scoring things	$200	
Machine parts	$1,500	
Propaganda/buttons	$500	
Uniforms	$1,000	
Regional - bus	$3,000	
Regional - hotel	$3,500	
National - bus		$1,500
National - air		$10,000
National - hotel		$15,000
Awards/banquet	$500	
Shipping robot	$0	
Tools/supplies	$1,500	
TOTAL	$17,300	$30,500
GRAND TOTAL	**$47,800**	

IV.3.2. Ethics and Responsibility: As college students interact with high school students, several issues need to be addressed. The high school students are typically minors (under 18) and must be treated as such. The senior design team will reinforce training to present professional image. All actions and treatments must reflect the best interest of the students and promote professionalism.

The team must assume the responsibility given by the school district when interacting with students at the high school. All mentors are encouraged to take the role of parents while teaching or training the high school students. The college students are responsible for their well-being and for training them according to the guidelines set by the school district.

All individuals are advised to follow safety measures while working in the laboratory. Safety considerations such as wearing of safety glasses must be adhered to at all times and a mentor must be with the students when operating machinery.

Group discussions were held to brainstorm ideas and solutions for the project task and the goals of the team. Communication and leadership were used to develop positive attitudes towards a productive environment for all members of the team

IV.3.2. Fundraising: Since considerable finances are needed to participate in the project fundraising becomes an important function of the teams. Fortunately, the FIRST team has excellent sponsors – however, students must still raise a fair share of money. The major contributions are: the local school grant money ($6000), corporate sponsorship from Proctor and Gamble ($5000), school district grant ($4000), Miami University ($1000).

In order to attend the national Championship, the team is seeks pledges. For the past few years, each student has raised $350-$420 in order to fund their share of the travel to the FIRST National Competition. Varieties of fundraisers are held over the course of the year to raise the money. Some students might need to pay an amount out of their pocket (or their parents) to make up the difference of what was not fundraised. In previous years, students participated in various fundraising events, such as selling “Buddy” cards, candy, Valentine’s Day flowers, soft drinks, and hot dogs at golf outings as well as building clocks for Craft Shows. Through the new partnership, the team obtained equipment, such as Bridgeport vertical machine, metal working lathe, a band saw and various power tools.

IV.4. REFLECTION AND ACTING

One way to define reflection is to self-assess one’s performance in achieving a certain task. The question is how well did you perform in this course? How did you arrive at this conclusion? Another way to define reflection is to compare and contrast the course objectives to what actually happened. For example, the main objective of the course is to *utilize the application of the senior students’ knowledge in science, mathematics, and engineering to perform a major open-ended design project.* The question now is: were you able to do that? Why or why not?

Another course objective is integrating liberal education goals (i.e. critical thinking, understanding contexts, and engaging with other learners) and professional engineering goals. Again, the students evaluate their experience with regard to this objective. In their opinion, did the course achieve the Miami Plan’ requirement for a capstone experience? Why or why not?

The students are required to write to submit an essay incorporating:

- Team work: Theirs and the partners’ ability to perform in a team.
- Communication: Their ability to document the research, to present the results, and to communicate with the advisor, team members, and customer.

- Design: Their ability to perform an open-ended design problem. Evaluate this experience versus other engineering courses? Explain.
- General skills and knowledge, such as AutoCAD, computers, theory, electronics, machining, etc. Evaluate their abilities to apply such skills in your project?
- Learning to learn on their own: Evaluate this aspect of performance in this course?
- Performance in general: Evaluate their own performance. What did they do well and what can be improved? What are the lessons they learned in this experience?

An example of the reflective essay prepared by the senior students participating in FIRST robotics competition is shown in Appendix A.

V. ASSESSMENT TOOLS

The following assessment tools are used in the course by the instructors to facilitate student evaluation:

- Presentation Evaluation (a panel of judges evaluate student projects and presentation at the end of each semester) (Appendix-B)
- Liberal Education Survey (Appendix-C)

The assessment tools used by the course instructors to assess the success of the course:

- Student Evaluation (divisional student evaluation done at the end of the course)
- Two Minute Survey (usually done after each guest speaker)

VI. SUMMARY

The use of Robotics competition as a senior design project is helping in the 'early immersion' of high school students into various aspects of the education at college level. They learn not only the basic principles of robotics design and construction- but also the financial and other important concerns that govern most 'real-life projects'. The University students are achieving a good understanding of the four goals of liberal education as applied to conducting a real world project. They achieve results through critical thinking, understanding contexts, engaging with others, and reflecting and acting.

High school students are learning to involve in teamwork in many ways. There are several opportunities available for students such as team leadership positions, mechanical design, electrical design and software development, shop management, parts fabrication, assembly, marketing, publicity, public relations, journalism, media publications, fundraising, CAD and 3D Animation, strategy development, robot operation and game play.

Team adult sponsors are being encouraged to help in any way they can assist the team. The efforts of these sponsors are student-focused and within the spirit of FIRST. As shown in the following Table, There is a variety of ways that the students are being mentored.

TABLE-4

• Mechanical Machine Design • Electrical Design & Wiring • Software Devel. & Programming • CAD – Design, Drafting, Animation • Metalworking & Part Fabrication • Carpentry & Construction • Project Leadership	• Marketing & Public Relations • Fundraising & Financial Management • Video & Graphical Publications • Machine Shop Management • Strategy Development & Coaching • Travel Coordination • Event Planning

Adults volunteer their time to act as coaches and mentors by working with the students after work hours and on weekends.

The Team keeps active in the local community, as they host events, make demonstrations, and support other math and science-related programs for the area's students. These events and activities include:

- FIRST Lego League mentoring (Aug.- Dec.)
- FIRST Workshop TBD
- FIRST Robotics Competition (Jan-May)
- Indiana Robotics Invitational (July)
- Numerous demonstrations (all year)

The competition is a unique opportunity to expose high school students to the thrills of careers in engineering science and technology. All through the competition, the advisors and the college students work toward establishing educational and career goals and:

- Inspire students about technology
- Prepare students for leadership roles
- Promote the ideals of FIRST
- Increase awareness of science and technology education opportunities in the community and state
- Introduce students to positive role models

The benefits are amazing for all members of the FIRST team. The students learn skills from professionals; the professionals will find a revitalized interest in their work. The local companies have well trained individuals interested in employment. The high school teachers will have examples for "real-world" applications for their academic courses.

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APPENDIX

REFLECTIVE ESSAY

Senior Design Group reflection on the FIRST competition

To accomplish the given task of the contest, the team of high school students along with mentors and senior design team had to be divided into teams. The purpose of this was to get ideas out in the open and begin all phases of the project. By having separate teams, many different tasks could be done at the same time without delay in the build process of the robot. Teams of five to six high school students worked with a senior design member along with a mentor. The division of the teams and what each did are as follows:

- *Base team- responsible for designing the base within the size restrictions, also in charge of laying out all the components that went onto the base.*
- *Hook team- responsible for designing a hook system to latch onto a goal and keep hold of it throughout the entire match.*
- *Ball colleting team- designed a system to collect balls and put them into the goal.*
- *Controls team- responsible for programming the robot, and operate all the motors on the machine.*
- *CADD team- group responsible for drawings of each part of the robot.*

Each student had there own ideas of what how the robot should operate, by placing students into teams and discussing ideas the best designs were determined. Each student did calculations and drawings with the help of the senior design group and mentors.

Team's reflection on Design criteria

As we anticipated, the overall design criteria have remained similar to previous contests. The footprint of the machine must be no larger than 30 X 36 inches. The total height must remain less than 60 inches and the weight must be less than 130 pounds. The machine must be operated using the 12-volt sealed lead acid battery provided by the supplier. In order to make the contest as fair as possible, additional parts and hardware are also limited as follows. The material usage is limited to the kit of parts, supplied through the contest, which include motors, electrical components, springs, pneumatic devices, and various other apparatus. There is an acceptable usage of additional hardware allotted to each team, which is limited in size, dimension, quantity, and material. The final restriction on materials states that any part on the machine that is not from the kit, or accounted for in the additional hardware list must be purchased from Small Parts, Inc. This company has issued a credit of $425 to each team. While there is no limit to how much a team can spend while building their robot, all parts used on the final robot must account for no more than the $425 amount.

As in past years, the kit of parts included a similar assortment of motors with the addition of a Mabuchi motor. For this years robot we were able to utilize three Bosch drill motors for the drive and ball conveyor systems. When dealing with the guidance system, last years basic program proved to be of little use. Unlike last years machine, this year's entry included a tank drive system and compressor, which was used to run a pneumatic cylinder for the hooking mechanism. All of this had to be incorporated into the basic program. As stated above, many of our electrical courses added in this phase of the design. As with last years design, however, we were unable to incorporate principles from ENT 412 Neural networks and fuzzy logic.

Statics and Dynamics also played a key roll in designing this year's robot. One of our most important decisions came when deciding between speed vs. torque. Do we want a fast robot with less pulling power or vice versa? In deciding this, we calculated the motor torque for both high and low gearing, the frictional forces involved with using a track drive vs. wheels, the velocities we could expect from both drive systems and how we could optimize the different outputs through various drive gear ratio's.

Another key aspect of our robot design was the hooking mechanism that was used to attach the robot to a goal. A double hook design, much like those used for lifting large blocks of is or logs, was thought to be the best method of attachment. However, the actuation of this system was less clear. Various concepts were worked through, including the use of a screw drive. In the, however, it was decided that a pneumatic cylinder would be the best method. Drawing on our Fluid Mechanics knowledge, we were able to design a pneumatic system that would operate within the guidelines set aside by the competition, as well as, provide enough clamping force to latch onto and hold a 160 lb goal.