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Embedding a National Collegiate Design Contest into a Course

by

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Abstract

To promote creativity and inspire innovation through the use of unstructured and open-ended problems, the design project for *Machine Design* this past year at St. Thomas was based on a national collegiate design contest: the 2003-4 ASME (American Society of Mechanical Engineers) Student Design Contest, *Mine Madness*. *Mine Madness* entails designing and manufacturing a vehicle from scratch to retrieve simulated mines from a simulated minefield within an allotted time. Students embarked upon an exciting educational journey which is documented (through text, photos, and available video) from the professor's perspective; starting with project inception through course end, to the official design contest itself at the regional level, and for some, continuation as another course project. Student teams participated in all steps of the design process: requirements analysis, conceptual design and trade-off, detailed design, manufacture, and performance testing. Usage of the ASME Student Design Contest was a great success. General pedagogical issues are examined and suggestions for application to future *Machine Design* course offerings are presented. A major conclusion is that one should not feel obligated to insist that the course design project is exactly the same as the national collegiate design contest. Rather, key aspects of the design contest (defined as a requirements subset) can be emphasized. For example, concerns over proper scale, can and should, override strict adherence to the contest rules. Another conclusion is that students are very motivated to work on this type of project because the national collegiate design contest has a reputation for being a high quality project. They also appreciate the possibility of continuation and recognition opportunities after the course is completed and become exposed to the sponsoring professional engineering society (e.g. ASME) at the student level.

Keywords: student design contest, machine design project, mechanical design, professional engineering society, ASME

1. Introduction

In mechanical engineering courses that emphasize design heavily, the creation and/or selection of an appropriate design project for the students can present an interesting problem in itself for the professor. This is a question to be taken seriously since a significant portion of the course (certainly true in a course like *Machine Design*) is devoted to the project to give students a high quality design experience. Should one use a design contest affiliated with a professional engineering society, an industrial project, a tried-and-true idea, or perhaps create a new project and/or contest? These are examples of the types of questions that one naturally ponders, along with careful consideration of the course objectives/outcomes prior to arriving at THE design project for the course. Once selected, and the course is underway, it is difficult to make any significant changes; nor would want to. Other considerations and issues may include such things as personal or institutional preferences, interest in variety/freshness, level of effort required for preparation and time available, and lessons learned from the past. The author has considerable experience working in industry (close to a decade), advising students on industrial design projects (as in *Senior Design*), as well as in the use of some tried-and-true design contest ideas (such as the mousetrap-powered vehicle design contest[1] [1]), but has never used a national collegiate design contest in a course before. Within the Engineering Department at St. Thomas, students have competed in a national collegiate design competition before (SAE Mini-Baja [2]), but never as part of a course. Such contests promote creativity and inspire innovation through the use of unstructured and open-ended design problems – desired and essential attributes of future real engineers. This past year in *Machine Design* (ENGR 320 [1,3]) one goal was to test out usage of a national design contest as a course project. Aspects of the ASME (American Society of Mechanical Engineers) 2003-4 Student Design Contest, *Mine Madness* were embedded into the *Machine Design* course and below we document (through text, photos, and available video) and draw conclusions from the exciting educational journey embarked upon by the students, starting at the beginning of fall semester, proceeding to the official design contest itself, and for some, to the end of spring semester.

2. *Machine Design* Course

Machine Design at St. Thomas is a required 4 semester credit course typically taken by students in the fall of their junior year; see [1] for the 2000-1 course description, including that year's project. At this juncture, they've had some exposure to design but haven't yet really worked on a significant long-term design project; especially one that utilizes many of the freshman and sophomore courses in science, engineering, and mathematics. The course description and objective are given by:

Course Description (from 2002-4 Undergraduate Catalog): Machines are designed to transmit motion and energy between two sites and convert motion from one to another. This course will develop the student's creative skills in conceptualizing machines to meet performance criteria. Machine designs will require the understanding and use of machine elements such as springs, screws, bearings, and gears. The student will participate in concept feasibility evaluation as a method of understanding component operational principles and failure modes.

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[1] One problem with any tried-and-true idea these days is that proven design concept data is readily available over the internet.

Objective: Machine design is a creative, multidisciplinary activity that builds upon knowledge acquired in such fields as statics, dynamics, and kinematics. Students will learn advanced mechanics concepts and become exposed to a wide variety of machine components (e.g. fasteners, springs, gears, linkages, bearings, cams, etc.) and understand their limitations via failure theories. An integrated design experience with a computer-aided-engineering (CAE) emphasis will provide an opportunity for application of principles learned, including limited manufacture.

3. 2003-4 ASME Student Design Contest *Mine Madness*

Mine Madness entails designing and manufacturing a vehicle from scratch to retrieve simulated mines from a simulated minefield within an allotted time. Requirements are described in great detail on the official website [4] with Table 1 providing an abbreviated list of requirements/issues sufficient for our purposes. Key design challenges concern the presence of obstacles (i.e. standard 4 x 4 and 4 x 8 lumber laid on its side) between the starting location and various mine locations in addition to basic locomotion, stability, steering, and "mine management" (i.e. acquisition, stowage, and deposition) – assuming use of some sort of ground vehicle.

Table 1 Abbreviated *Mine Madness* Requirements/Issues

1. Battery power	8. Mines are to be carried above the surface of the minefield
2. Umbilical cord (if used) can't interfere with machine	9. Mine receiving area indicated
3. 400 mm x 300 mm x 300 mm rectangular box encloses machine	10. Starting logistics, timing, and bonus point system described
4. Minefield: 1.5 m x 3.5 m flat, level surface with 2 x 4 lumber perimeter railing	11. Additional trial
5. Obstacles: 4 x 4 and 4 x 8 lumber	12. Scoring details
6. Machine initially in starting volume: 300 mm x 300 mm x 300 mm	13. Diagram available with mine point values
7. 6 mines located throughout the minefield	

4. Project Definition, Activities and Evolution

Project Definition: Initially, the course project was defined to be exactly the same as the *Mine Madness* contest. One thought that played into this decision concerned the maturity level of students on a yearly basis within the BSME program. Freshman and sophomores typically aren't far along enough to work on such unstructured open-ended design problems and seniors should probably be focusing on industrial projects (author's opinion). This leaves juniors as ideal for participation in national collegiate design contests.

A design report was also required with the following content and grading for the entire project (also tied to many of the ABET course outcomes):

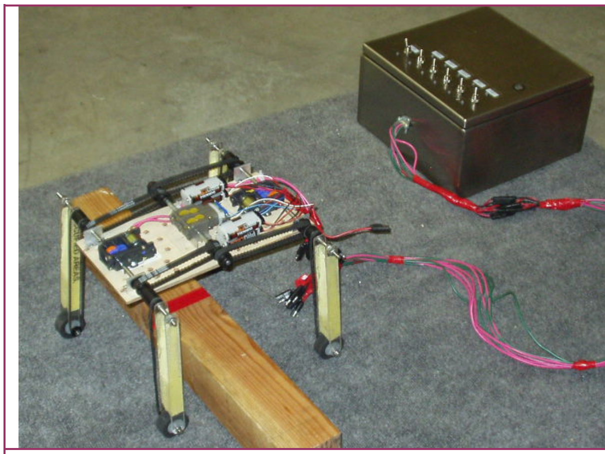
1. Engineering Specifications (5%)	5. Manufacturing Process Identification (5%)	9. Cost Analysis (5%)
2. Concept Tradeoff Chart (5%)	6. Design for Assembly (DFA) Analysis (10%)	10. Work breakdown Structure (WBS) + Schedule (5%)
3. Solid Model (20%)	7. Photograph (5%)	11. Power Point Presentation (10%)
4. Static and/or Dynamic Analysis (20%)	8. Performance (5%)	12. Background Information (5%)

Approximately 8 weekly 3 hour laboratories were allocated for working directly on the design project with a budget of $125 per design team. Four teams were created (2 per laboratory section), 2 small "competition" teams with 4 students each (maximum allowed), all of whom expressed interest in going to the Region VII Regional Student Conference (RSC) in Lincoln, NE and 2 larger teams comprised of the remaining students in their respective laboratory section (8-10 students each). To promote equality, the large teams were asked to perform more engineering analysis activities (Solid Model, Static and/or Dynamic Analysis, and Design for Assembly (DFA) Analysis) than were the smaller teams.

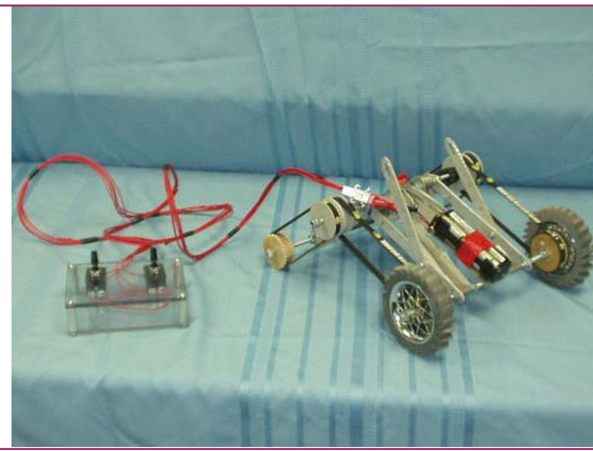
Activities and Evolution: The very first activity was to discuss the requirements in great detail. Questions naturally arose and clarifications/interpretations were sought as an entire laboratory section, occasionally using the Q & A webpage on the *Mine Madness* website. Conceptual design was the next activity, and in many respects the most difficult. A traditional brainstorming session (e.g. Adams [5]) was implemented semi-privately with each design team focusing initially on how to "get-over-the-wall" (believed to be THE tough problem and a good place to start the design effort) with the professor moderating the session, but not biasing the team member's thinking. Students also knew that the professor didn't know the optimal solution to the problem and idea generation was initially slow and very "fluffy." However, over the ensuing weeks ideas were fleshed out, further refined, traded-off, and an idea selected that was endorsed by each team. Four very different ideas (on a per team basis) emerged and teams were committed to them for purposes of completing detailed design, manufacture, and performance testing. Two design teams pursued specially configured "articulated-tracked" vehicle concepts and 2 design teams selected legged-locomotion concepts. At this stage of development it became apparent (based in part on student feedback) that solving the entire *Mine Madness* problem was too difficult in the time allocated so the design problem was simplified to focus exclusively on "getting-over-the-wall," i.e. the 4 x 4 or 4 x 8's and no longer was stability, steering and mine management functionality required. That said, design teams were advised to plan for the addition of eventual steering and mine management modules to be incorporated (in a stable sense) into their machines. Detailed design and manufacturing ensued with students heavily utilizing the CAD system (SolidWorks [6-9,10]), machine shop, and machine component suppliers (note: no "parts kit" was provided). The latter comment is important since most students were totally unfamiliar with where to find and purchase real industrial grade parts; an essential skill for mechanical design engineers. For critical components, internet buying from industrial suppliers with overnight, 1, or 2 day delivery from anywhere in the US was the norm. As an aside, a local military surplus store (i.e. Ax Man) famous for low-cost miscellaneous mechanical and electrical "componentry" (often in various volumes and quality) was quite popular amongst the design teams – so was our machine shop's scrap pile and supply chests! Also, scrounging was not only tolerated, but encouraged.

5. End-of-Semester Course Design Contest Event

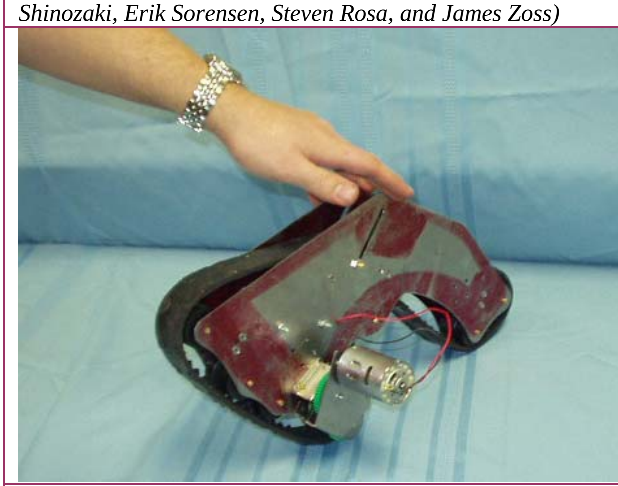
With contest day looming, students worked at an intense pace days and evenings before and all design teams arrived with very respectable machines. Parents, faculty, friends, and other engineering students were invited to the festive event. Individual teams participated in a photo session, described their machines, and demonstrated an operational test of their machine (also video-taped) trying to climb over several walls representative of that used in *Mine Madness* (4 x 4, 4 x 8) – complete design reports were also prepared and due at semester's end. Figure 1 illustrates photos of all 4 named machines (note: based on its performance, "foal" is my choice of moniker).



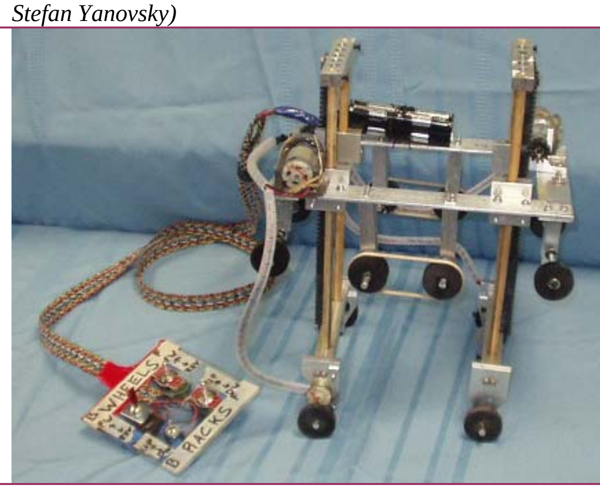
"Foal" *(Amber Beck, Jennifer Borofka, Jay Brecke, Christi Hoffman, Timothy Jorgenson, Todd Seigel, Daniel Shinozaki, Erik Sorensen, Steven Rosa, and James Zoss)*



Honeybot *(Joseph Kattar, Kenneth Oatman, Mark Onwuji, Robert Roberts, Nickolas Spalding, William Stipe, and Stefan Yanovsky)*



Juggernaut *(Nickolas Dalbec, Luke Hacker, Andrew Johnson, and Thaddeus Klabacha)*



Turtle *(Titus Amundson, Kelly Kanz, Evan Moyer, and Brian Shovelain)*

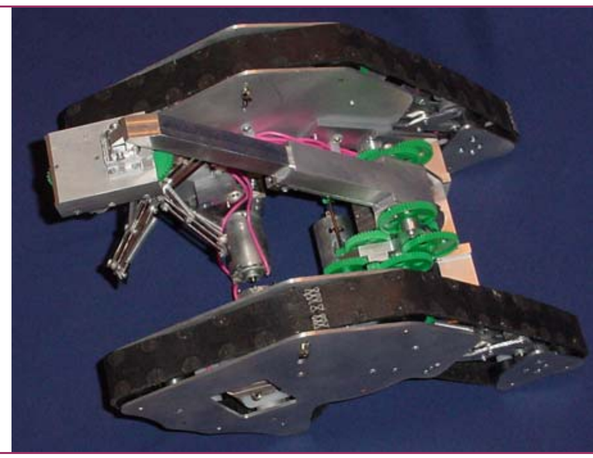
Figure 1 "Getting-over-the-wall" machines on contest day at the end of *Machine Design*, fall semester 2003.

Regarding performance, it is worth noting that both "articulated-tracked" vehicle designs were superior to the "legged-locomotion" machines. This was a learning experience for all involved and it was fun to become familiar with the different machines created and design approaches tried. Modest awards (i.e. brand-new rolls of 3M transparent duct tape or "MAGIC tape!") were given to the team(s) with the best performing machine as determined by several adjunct faculty judges (Roy Jenson and Keith Zell).

6. Performance at the ASME Region VII RSC Student Design Contest

Based on the performance of their machine at the End-of-Semester Course Design Contest event, 2 of the 4 design teams decided to prepare a machine for entry in the ASME Region VII RSC Student Design Contest, held at the University of Nebraska, Lincoln on March 12, 2004. This entailed adding functionality (steering and mine management to be specific, possibly along with stability) to their machines over a period of approximately 3 months – an additional $250 was made available to interested teams. Reliability and performance enhancements were also worked on during this time. Figure 2 shows the 2 machines prepared for the RSC. Of the 2 machines, only 1 machine was "complete" in time for the official RSC contest (i.e. Honeybot). At the contest in Lincoln, NE it made a very respectable invited post-contest exhibition run (vs. an official run due to an unfortunate last day wiring problem [11] – see Figure 3, video available [12]). Congratulations to Team Honeybot! As for Team Juggernaut, their machine remained home and was completed as a course project by one of the team members (Luke Hacker) in *Manufacturing Processes* (ENGR 371 [3]) during spring semester and is now locally famous for its impressive CAD model (see Figure 4), precise and extensive component fabrication, and superb craftsmanship – congratulations to them as well!

Honeybot *(Mark Onwuji, Robert Roberts, William Stipe, and Stefan Yanovsky)*



Juggernaut *(Nickolas Dalbec, Luke Hacker, Andrew Johnson, and Thaddeus Klabacha)*

Figure 2 Machines prepared for entry in the 2004 ASME Region VII RSC Student Design Contest (Honeybot on contest day and Juggernaut as shown completed in May 2004 timeframe).

Figure 3 Team Honeybot and machine at ASME Region VII RSC Student Design Contest during set-up just prior to their exhibition run (Robert Roberts, Mark Onwuji, and Stefan Yanovsky shown).

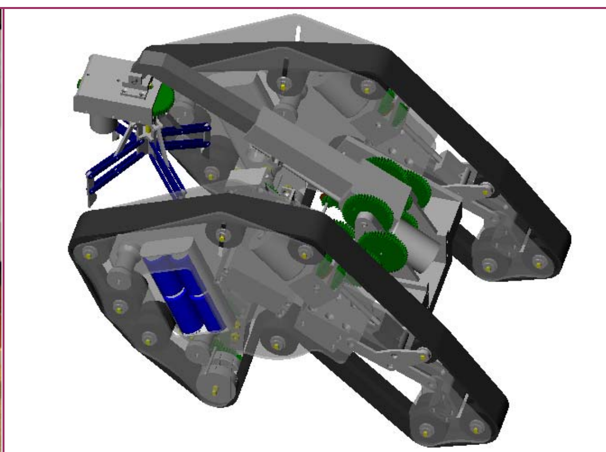


Figure 4 Juggernaut SolidWorks CAD model (Luke Hacker).

7. Conclusions

In general, usage of the ASME Student Design Contest *Mine Madness* was a great success – written course evaluation comments from the students also support this conclusion. However, a major conclusion is that one should not feel obligated to insist that the course design contest project is exactly the same as the national collegiate design contest. Rather, key aspects of the design contest (defined as a requirements subset) can be emphasized. For example, concerns over proper scale, can and should, override strict adherence to the national collegiate design contest. Another conclusion is that students as very motivated to work on this type of project because the national design contest has a reputation of being a high quality project. They also appreciate the possibility of continuation and recognition opportunities after the course is completed and being exposed to the sponsoring professional engineering society (e.g. ASME in this case) at the student level. Finally, as one may suspect, results are somewhat independent of team size (within a factor of 2), so there is no guarantee that a large team will produce a better machine than a small team. For future reference, a team size in the 4 range is preferred.

Acknowledgements

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[11] *ASME Minnesota News*, Issue 91, ASME Minnesota Section, Spring 2004.

[12] *ASME RSC (VII) 2004 "Mine Madness" Design Contest* video shot by M. P. Hennessey and edited by J. A. Faeth, March 2004.