AME40463
Mechanical Engineering Senior Design
The University of Notre Dame
Class of 2009

March 13, 2009

Contents

1 Introduction

The objectives of this course are,

1. to provide you with an experience that requires active student participation,
2. enhance your skills related to engineering design methodology, including modeling, simulation and Feasibility Studies
3. experience the mechanical engineering product development process,
4. illustrate the interaction between competing technical and non-technical issues and the role of compromise, constraints and merit,
5. provide exposure to various phases of the design process, from the definition of requirements, specifications and constraints, to product realization,
6. help to develop an understanding of the planning, coordination and communication required in a team and a multi-team effort, and
7. allow you to be innovative.

In realizing these objectives, the intent is that this course be a capstone mechanical engineering experience which brings together many of the concepts that were introduced in your undergraduate curriculum. The three final products of the course are:

1. your Design Team's Concept Design Proposal to develop an electromechanical system,
2. a prototype of that system which you and your team members will design, fabricate and demonstrate,
3. a demonstration of your Squad's abilities in the Blue-Gold game of Mechatronic Football.

Properly done, these final products are each sufficiently complex so that no single individual can complete any of these tasks alone, in the given time frame. The tasks require the organized efforts of a Design Team, which is a team to which you will be assigned, as well as the organized efforts of a group of Design Teams, which is the Squad to to which your Design Team belongs. Thus this project involves *two levels* of team work.

The remainder of this document consists of sections which describe in detail the project and your responsibilities. It includes:

Section 2 Course Organization
Section 3 Request for Proposals and Product Description
Section 4 Semester Schedule and Deliverables
Section 5 Feasibility Study Reporting Requirements
Section 6 Concept Design Proposal Requirements
Section 7 Engineering Notebook
Section 8 Comments From Previous Students
Section 9 FAQs
Section 10 The Squads and Design Teams
Section 11 Attachments

AME40463 Ltd. Management:

Michael Stanisic, Preliminary Design Review Evaluator and General Consultant
369 Fitzpatrick Hall of Engineering
stanisic@nd.edu
Generally available on a walk-in basis, although email appointments are recommended.

Mihir Sen, General Consultant
368 Fitzpatrick Hall of Engineering
msen@nd.edu
Generally available on a walk-in basis, although email appointments are recommended.

Gregory Brownell, Microprocessor and Electronics Consultant
ISALL Lab, 358C Fitzpatrick Hall
brownell.1@nd.edu
Generally available on a walk-in basis, although email appointments are recommended.
Mr. Brownell and the ISALL Lab is unavailable to you M-F from 2:00-4:00 p.m.

John Ott, Facilities Manager
377 Fitzpatrick Hall
jott@nd.edu
Available for consulting by email appointment only.

Leon Hluchota, Master Machinist
108 Cushing Hall, AME Machine Shop
Leon.Hluchota.1@nd.edu
Available for consulting by email appointment only.

Richard Strebinger, Senior CAD/CAM Engineer
375 Fitzpatrick Hall of Engineering
rbs@nd.edu
Available for consulting by email appointment only.

AME40463 Ltd. Staff:

Jeremy Newkirk, CAD/CAM Certifier and Manufacturing Consultant, jnewkirk@nd.edu
Benson Mitchell, Machine Tool Certifier and Manufacturing Consultant, Mitchell.123@nd.edu
Chandan Mozumder, Feasibility Study Evaluator and Consultant, Chandan.K.Mozumder.3@nd.edu
Huade Tan, Human Resources, Huade.Tan.24@nd.edu
Michael Giordano, Design Notebook Evaluator and Comptroller, Michael.A.Giordano.2@nd.edu

2 Course Organization

This course represents the capstone project in your undergraduate mechanical engineering education. You are to think of it as a professional experience and conduct yourself as if you hold a position in the "company", AME40463 Ltd. Your success, your Design Team's success, and your Squad's success are closely linked in this course. You must also keep in mind that this is an academic course and thus it will contain elements like presentations, reports and grades. As in most courses, the benefits you gain will be proportional to the amount and quality of the time and effort you expend.

Another feature of this course, unlike most others that you have taken, is that not everyone will experience and learn the same things. Depending upon those parts of the project that you focus on, your learning experience will be different from others in your Design Team and your Squad. You will be asked to share your experiences and knowledge with others in your Design Team and Squad so that all can benefit from your efforts and the Squad's overall chances of success will be enhanced. Hopefully, you will be given the chance to focus on issues and topics of interest to you, but this is not always the case, and you must be prepared to learn whatever is necessary for the success of your Design Team and your Squad.

2.1 Job Description (i.e. Course Requirements)

Each company employee will be assigned to a Design Team containing either four or five engineers. Each Design Team will be responsible for the development of a product concept, preparation of a Concept Design Proposal, the fabrication of a prototype and a demonstration of the prototype.

Some of the subsystems for the prototype will be purchased from vendors (i.e. outsourced), some subsystems that have been salvaged from previous efforts will be provided by Management and some will be fabricated by the Design Team. Outsourcing as much as possible is strongly recommended. Relying on parts scavenged from previous projects is dangerous and typically indicates a lack of good engineering and more of a "put something together" approach, which is almost certain to fail. Fabricating subsystems takes a considerable amount of time and should be avoided if outsourcing is possible.

This project provides you the opportunity to apply some of the knowledge gained and skills developed throughout your academic career. It is a challenging project and in order to accomplish the project in the limited time available and the inflexible end-dates for the semester, there is a rigid schedule and several fixed milestones. There are a number of deliverable items, some due from Individuals, others due from the Design Teams, and finally the Blue-Gold Game due from each Squad. Each employee (student) should make every effort to satisfy all of these requirements in a timely manner, as this is the best way to ensure success in both the course and the project. Crisis management, i.e. waiting until the last minute, does not work well here, or in any other situation where your results are needed by others. It will not be appreciated by your teammates and will likely lead to a low compensation (grade).

This job will require an average of approximately twelve hours per week (five hours in class and seven outside of class) on your part, so plan your semester's activities accordingly. There is no right answer in this project. Individually, as a Design Team and as a Squad, your results will depend upon your abilities as mechanical engineers and the level and quality of effort you expend.

2.2 Organizational Structure

The class is divided into two "Squads", Blue and Gold. Each Squad consists of eight "Design Teams". Of the eight Design Teams in either Squad, five of them will have four members and three of them will have five members. One of the first tasks of each Design Team is to establish roles and responsibilities for each of its members. Each Design Team must select a Team Leader. All Design Team members (including Team Leader) take responsibility for one or several of the following, CAD/CAM, manufacturing, treasurer, interfacing with the programming and electronics teams. It is strongly recommended that more than one team member be associated with each of the responsibilities. For example, you cannot expect one individual to manufacture all the parts. Also, more than one team member should be in close contact with the electronics and programming Design Teams. In the past, some frustrating situations have occurred when one person was given sole responsibility for a certain aspect of the project, and for one reason or another, failed to follow through on their responsibilities. Having more than one individual responsible for each aspect is very important. Also, establishing and maintaining a good team dynamic should be one of your most important goals in this course since your team (which includes you) is not likely to succeed without one.

2.3 Salary (i.e. grading)

Your grade (salary) will be determined based on your performance and that of your Design Team and your Squad. The performance will be evaluated on both your individual deliverables and those of your Design Team and Squad.

a. Individual Deliverables:

Individual reports/memos (e.g. individual concepts, Feasibility Study), engineering notebook, presentations, etc., described later.

b. Design Team Deliverables:

Team Concept, Prototype, Concept Design Proposal and Critical Design Review, etc, described later.

c. Squad Deliverable:

Performance at the Mechatronic Blue-Gold Game.

Each Design Team's Deliverable share of this Squad Deliverable is based on information from the Design Team Leaders evaluation of each Design Team in their Squad. An individual's share of the credit for the sum of the Design Team Deliverables is determined using information from your Design Team's peer reviews. Deadlines have been established for each of the Deliverables and they must be strictly complied with. Failure to submit any of the required items may result in dismissal from your job (i.e. an F in the course). Additional details on how each of the required items will influence your salary are provided below.

Individual Deliverables: (50% of your total salary)

- 15% from your individual concept memo
- 20% from your individual Feasibility Study proposal
- 25% from your individual Feasibility Study
- 25% from your Preliminary Design Review (PDR) presentations
- 15% from your engineering notebook

Design Team Deliverables: (50% of your salary)

- 15% CAD Evaluation
- 25% Concept Design Proposal (first draft)
- 5% Concept Design Proposal (final draft)
- 15% Layout of all mechanical parts (for Design Teams other than electronics or programming)
- 15% Demonstration of electronics, sensors and control logic (for electronics or programming Design Teams)
- 20% Your Design Team's share of the Squad points earned
- 20% Critical Design Review presentation

2.4 Vacation Policy (i.e. attendance)

AME40463 Ltd. provides six weeks of paid vacation for its engineers each year. During a fourteen week period of time (i.e. one semester), this corresponds to one and a half weeks. **Simply put, you can be absent a total of three of the T-Th classroom meetings without loss of pay (grade). Anyone violating this vacation policy will receive a reduced grade (salary)**. Specifically, after your third absence your grade will be reduced by one letter for each additional absence. What this means is that if you finish the course with an A grade, and are absent for seven classes, your Final Grade will be an F. If you finish the course with an B grade, and are absent for six classes, your Final Grade will be an F, etc.

A tardy of more than 1 minute is considered one third of an absence and a tardy of greater than twenty minutes is considered an absence.

2.5 Design Room Policy

The Systems Design Lab, B-19 Fitzpatrick Hall, is available for your use whenever Fitzpatrick Hall is open. Each Design Team will be allocated a work area which includes a mechanics tool set, an electronics tool set, secured storage space, meeting area and fabrication space. The lab also contains a general meeting area and the majority of the fabrication equipment you have available to you. The lab has been developed at considerable expense and it is the responsibility of each class member to make sure that this equipment is used only for the purposes of this class and is used in a safe and responsible fashion. You have access to the Lab whenever Fitzpatrick Hall is open. The room is equipped with a combination lock and you are not to provide this combination to anyone not taking the class. No music or radio playing is allowed in the lab.

2.6 Spending, Cost Accounting and Equipment Accountability

Each Squad will be allocated up to $7,000 from AME40463 Ltd. for development of their *entire* team. Team Leaders of each Squad will decide how to distribute these funds to the Design Teams of their Squad. Any item costing more than $300 requires the approval of Dr. Michael Stanisic.

Funds may be used by a Design Team to purchase,

- raw materials
- outsourced components
- outsourced services
- parts and services provided by the company.

Each Design Team must maintain an itemized list of expenditures. Itemized Receipts or Invoices for each purchase is required in order to receive a reimbursement. Packing Slips do not qualify for reimbursement, ONLY Receipts and Invoices. The itemized expenses should be numbered in correspondence to the numbering of the receipts and invoices. An envelope containing these can be submitted to Management on March 25^{th} and April 21^{st} for reimbursement. Reimbursement will be made to the Treasurer who will distribute it to the Design Team members. The Design Team is also allowed to invest up to a maximum of $30 per team member towards the project, which will not be refunded. The company is able to provide each Design Team used equipment at no expense. A list of this equipment can be found at the ISALL website `www.nd.edu/~isall`. Be warned, these components are used and they may not be completely functional. *It is your responsibility to test the functionality of these components. Do not assume they are functional.* You are also warned not to develop a design based solely around these salvaged parts. This is not good engineering. You have sufficient funds to purchase what you need. If used, all salvaged parts must be repackaged and returned to the company in the condition issued. Any broken parts, equipment, or lost tools, will be deducted from your Team's budget. Any donated services or parts will also have their value deducted from your Team's budget, so there is no point in seeking them.

2.7 Prototype Construction

The company has exceptional facilities for prototype construction. Equipment includes:

- Three drill presses*
- One scroll saw*
- One vertical band saw*
- One sheet metal shear and brake*
- Two sanders*
- One 2 hp. lathe*
- One 2 hp. vertical mill*

- Two fractional horsepower 2-D CAD/CAM work cells w/ ProE interface*
- One 1 hp. horsepower 2-D CAD/CAM work cells w/ ProE interface*
- One Stereo lithography Rapid Prototyping Machine w/ ProE interface△
- One Fused Deposition Rapid Prototyping Machine w/ ProE interface△
- One 3 hp. CNC Vertical Mill w/ ProE interface♠
- One 3hp. CNC Lathe w/ ProE interface♠

Before using the equipment marked * Team's engineers must be certified by Mr. Jeremy Newkirk and Mr. Benson Mitchell, Use of these machines is free of charge. Equipment marked △ is housed in the company's CAD/CAM facility in Cushing Hall. These machines can only be operated by Mr. Richard Strebinger, the company's CAD/CAM expert. There is a fee of $20/hr. for his time and $10/hr. for running time of the machine. You are discouraged from using these. Equipment marked ♠ belongs to the company's main machine shop in Cushing Hall and can only be operated jointly by Mr. Richard Strebinger and Mr. Leon Hluchota. There will be a $20/hr. charge for each of their time and a $10/hr. charge for running time of the machine. You are discouraged from using these as well.

To make proper use of the company's equipment, your Design Team must be well prepared and organized. Waiting until the last minute to try and use these manufacturing/fabrication machines will not be time effective. If you wait until the last minute your Design Team will likely spend a significant amount of time waiting in a queue to use a particular machine, alongside other Design Teams that also waited until the last minute. It is up to you to use your time effectively. Crisis management (waiting until the last minute) will result in a very inefficient use of your time. Design Projects are *Front Loaded*.

The prototypes as well as any other parts or tools purchased by your Squad remains the property of the company after the semester ends, regardless of how it was purchased or if it was donated. Do not attempt to return any parts to vendors for refund after the semester is over.

Most importantly, there are SAFETY RULES that are STRICTLY enforced. The first violation of any of these safety rules will result in a written warning, which must be signed by you. The next violation will result in your being barred from further using any of the manufacturing equipment and you will sign a statement agreeing to this. If you continue to use the equipment after being barred from such, you will be terminated (i.e. receive an F grade).

2.8 Safety Rules

1. Safety glasses must be worn at all times when operating or within 5 feet of any machinery.
2. You must wear hard soled and closed shoes when in the manufacturing area. No sandals etc.
3. You can wear no loose or baggy clothing and no long sleeved shirts when operating any machinery.
4. Any hair longer than below the ears must be tied back into a single "pony-tail", pulled in under your shirt and secured to your neck with a bandanna when operating any machinery.
5. You must clean up any machine you use. This means vacuuming the machine, any worktable it may sit on and the floor around the machine. You must dispose of any scrap materials.
6. Whenever using any of the machinery the lab, there must always be at least one other person within eyesight.
7. You must be Certified before you can use any of the machinery in B-19.

Unauthorized use of any machinery, or facilities, or any violation of the safety rules above is the surest route to your dismissal from the company and your failing the course. **Your safety is the primary consideration of this company.**

3 Request for Proposals and Product Description

The Game of Mechatronic Football

AME40463 Ltd. is responding to a request from the Commissioners of the MFL to demonstrate the game of Mechatronic Football.

3.1 Project Requirements

Each of the two Squads (Blue and Gold) must:
1.) Consist of eight Design Teams of four or five team members.
2.) Develop a team of at least eight players to play the game of Mechatronic Football.
3.) Play the game by the rules of 8 on 8 football, except where stated as otherwise in this document.

Each Design Team must:
1.) Develop the conceptual design for the prototype of one aspect of the game and document the design in the form of a the Concept Design Proposal. The design must be based upon sound engineering modeling, analysis and simulation. The proposal should include engineering justification for the product and address issues related to performance, manufacturing, control and assembly. Some of these issues will be presented before the entire Squad at the weekly Preliminary Design Review (PDR). The Design Teams of the Blue Squad will have their PDRs on Tuesdays. The Design Teams of the Gold Squad will have their PDRs on Thursdays. The total of the results of this concept development project will be presented in a Critical Design Review to a board of senior engineers from the company and the Commissioners of the MFL.
2.) Fabricate a "proof-of-concept" prototype for the proposed concept. The prototype will demonstrate MFL capabilities in a sort of Punt, Pass and Kick Competition and by a game played between the Blue and Gold Squads.

3.1.1 Squad Details

1. A team can consist of no less than eight players and no more than sixteen players.
2. AME 40463 Inc. will provide each team with sixteen sets of tackle force sensors.
3. Tampering with the sensors is considered cheating and is a violation of the University's Honor Code.

3.1.2 Player Details

1. Players will be remote controlled.
2. The controllers will be equipped with two, 2-axis joysticks and at least four pushbuttons.
3. Approximately five times per second the state of the joysticks and pushbuttons will be transmitted to the player.
4. The transceiver uses a ZigBee protocol and connects to its player using an SPI interface.
5. Autonomous actions by players are strongly encouraged.
6. Players must incorporate a microprocessor in some significant fashion.
7. All players except for the quarterback must be contained within a 14 inch x 14 inch footprint before the start of a play.
8. The quarterback may reach out beyond this footprint only to take the ball from the center.
9. Players can have no more than two extensible arms.
10. Arms can extend no more than 18 inches from the footprint when fully extended.
11. The extensible arms can consist only of rotational joints.

12. Beyond the 14 inch x 14 inch footprint, extensible arms can have no cross sectional dimension greater than 3 inches.

13. Each player must have a tackle force sensor along each side of its 14 inch x 14 inch footprint.

14. Force sensors must be mounted with their centers at a height of 6 inches above the ground.

15. A player carrying the ball cannot shield its tackle force sensor from contact by other players. If you have questions contact Dr. Stanisic who will be consult the Commissioners.

16. DC power only.

17. Any lead acid batteries must be sealed and of the gel type, more commonly known as a gel cell.

18. There are no height or weight restrictions.

3.1.3 Game Rules Superseding 8 on 8 Football Rules

The game will be played by the rules of 8 on 8 football, with the exceptions below.

1. The game will consist of two 20 minute halves.

2. The game will be played on a collegiate size basketball court.

3. From end to end, the court (playing field) will be divided into equal thirds.

4. There are no kick-offs or punts.

5. At the beginning of each half the receiving team begins play at the one-third mark in their own territory.

6. A first down is realized when a one-third span of the field is covered within 4 plays.

7. If the offense elects to punt, the receiving team is given the ball on the one-third mark of their territory.

8. A fumble is recovered by the first team to first touch the ball after it hits the ground.

9. The offense cannot advance the ball due to a fumble.

10. If the offense recovers its own fumble, the ball is marked at the spot of the fumble.

11. The end zones will extend 15 feet past the goal lines that define the playing field.

12. A player is considered out of bounds when any portion of its 14 inch x 14 inch footprint is crossing the inside of a sideline.

13. Before the game the offense must minimally demonstrate the ability to transfer the ball from the quarterback to a running back.

14. When in possession the ball cannot be contained, the ball must be held.

15. Concepts for holding the ball should be approved by Dr. Stanisic who will consult with the Commissioners.

16. The exception to this rule is in the event of a pass attempt. During a pass attempt the ball may be fully contained by the quarterback. When the ball is contained by the quarterback, the quarterback cannot advance the ball by running. To advance the ball by running the quarterback will need to return the ball to a held state.

17. The game ball is a miniature souvenir football.

18. Minor modifications to the ball may be allowed with approval of Dr. Stanisic who will consult with the Commissioners.

19. A tackle is achieved when a force of 5 lb_f is applied for a duration of 1 seconds to the tackle sensor of a player in possession of the ball.

20. Player substitutions are allowed between plays and during time outs.

3.1.4 Scoring Rules

1. A touchdown is worth seven points.
2. There are no point after attempts or field goals.
3. A completed hand off is worth 1 point.
4. A completed pass of 5-15 feet is worth 2 points. This is a *short pass*.
5. If a short pass is intercepted, 2 points are awarded to the defense.
6. A completed pass of more than 15 feet is worth 3 points. This is a *long pass*.
7. If a long pass is intercepted 3 points are awarded to the defense.

4 Semester Schedule and Deliverables

(ID) ⟶ Individual Deliverable
(TD) ⟶ Design Team Deliverable
(SD) ⟶ Blue or Gold Squad Deliverable

13 Jan.	First meeting.
	Course and policies overview.
	Project overview.
	Initiate project planning.
	Announce Blue and Gold Squads.
	Announce Design Teams of Blue and Gold Squads.
	Design Teams select their Team Leaders.
	Commissioners meet with entire class and with individual Design Teams.
	Programming and Electronics Design Teams meet with Dr. Schafer.
	Mr. Ott assigns lockers and tools.
	Mr. Brownell distributes electronics tools.
	Blue Squad Team Leaders meet at 7 p.m. and Gold Squad Team Leaders meet at 8 p.m. to organize squad and delegate Design Team responsibilities. Location is 365 FHE.
15 Jan.	Squad organization and delegation of Design Team responsibilities announced.
	Schedule of Preliminary Design Reviews announced.
20 Jan.	Individual product concept memo due. (ID)
22 Jan.	Design Team concept selection report due. (TD)
27 Jan.	Feasibility Study Proposal due. (ID)
10 Feb.	Feasibility Study due. (ID)
5 Mar.	Concept Design Proposal due. (TD)
17 Mar.	Bill of Materials due. (TD)
24 Mar.	Layout of all mechanical components. (TD)
26 Mar.	Demonstration of electronics, sensors and control logic. (TD)
9 Apr.	Demonstration of individual player and Squad capabilities, Stepan Center 9:30 am. (SD)
18 Apr.	The Mechatronic Blue-Gold Game, Stepan Center, 9 a.m. (SD)
21 Apr.	Revised Concept Design Proposal due. (TD)
	Design Team peer evaluations and course/project assessments due. (ID)
	Evaluation of prototype mechanics. (SD)
	Evaluation of prototype electronics and programming. (SD)
	Blue and Gold Squad Design Team evaluations by Design Team Leaders due. (SD)
	Final evaluation of Design Notebook. (ID)
	Critical Design Review (CDR) rehearsal.

23 Apr. Critical Design Review. (TD)
28 Apr. Lab clean up and tool check in. (ID)

4.1 Details on Individual Deliverables

20 Jan., Individual product concept memo.
A simple four to six page document that provides the multiple ideas or concepts for the required product and/or its subsystems. The first page (typeset) should include *an explicit statement of quantified specifications and constraints on the design.* The remaining pages should include multiple sketches of the product, or elements of the product, in order to assist in understanding its basic operation and form. Each of these will ultimately be copied and distributed to the entire Design Team for review and assessment. Sketches should be neat and understandable. **Team members should not talk to each other about ideas until after this document has been turned in**. Talking to each other will restrict your ability to think of ideas and this could lead to your Design Team's ultimate failure. If your team members all tend to have the same idea, this would be a direct result of not following this rule and you will find that you have short-changed yourself and your team and you will all suffer for this. *Your Design Team's concept selection is probably the single most important decision your group will make.* It is my opinion that the success or failure of your product is effectively decided after your Design Team has selected its concept. Selecting a poor concept will surely lead to failure, even if your Design Team invests infinite resources. Selecting a less than good concept will cost your Design Team an exceptional amount of time to develop a working system. Through the course of this semester, you will see that this is true. **This is the most critical stage of the design process. Throw your net wide and try to bring in as large a catch of ideas/concepts as possible. There is no such thing as a bad or stupid idea/concept. There definitely is such a thing as a missed good idea/concept.** See the evaluation form in section 11.

27 Jan., Feasibility Study Proposal
A one page document that proposes your engineering Feasibility Study. You should state what specific system component the study will involve. You are to define the Design Variables, the State Variables, the engineering model and the Measure of Merit. If there are any constraints on your Design Variables or State Variables they should be given. See the evaluation form in section 11.

10 Feb., Feasibility Study
This is an important source for the **quantitative** justification for the decisions made during the design process. It demonstrates the engineer's ability to develop analytical models and provide quantitative reasons for design decisions. The results must be based upon engineering modeling and principles. See the evaluation form in section 11.

21 Apr., Final evaluation of Design Notebook
Each engineer will submit their engineering notebook for review and evaluation. All of your activities in this project must be logged in this book. All entries are to be dated, with time of day and your signature. This is an important means of documenting your work and your choices. It also shows what you have contributed to the project and the significance of those contributions. See the evaluation form in section 11.

21 Apr., Design Team peer evaluations and course/project assessments
Management has provided you with an evaluation form that each individual will complete, one for each other member of the Design Team. Careful review of this form at the beginning of the semester will give you a good idea of what is expected of you and the important issues that will be used by your peers to evaluate your performance during the project. These evaluations are used to determine what percentage of the Design Team's deliverables grades are going to be applied to each team members final grade. See the evaluation form in section 11.

4.2 Details on Team Deliverables

22 Jan., Design Team concept selection report
Each Design Team will develop a two to five page report that describes the product concept which they intend to develop through their engineering analysis and Feasibility Studies. The report should detail key issues that they intend to address during the Feasibility Studies as well as a schedule of key deliverable items or milestones for the remainder of the project.

3 or 5 Mar., CAD Evaluation
During your PDRs this week your Team will present finalized CAD drawings. I will closely scrutinize your mechanicss. This includes appropriate use of fasteners, details on bearing mountings, details on how elements are connected to shafts, manufacturability, appropriate use of engineering materials (wood is NOT an engineering material)s, shaft couplings, adjustability for manufacturing imperfections, and whether it can be assembled. . **5 Mar., Concept Design Proposal (first draft)**

This is one of two primary products of the project. It is a formal engineering report to be viewed as a proposal from the Design Team detailing the feasibility of the product concept. Emphasis should be on quality of content and organization, certainly not on quantity. The document is limited to 75 pages (12pt. font, double-spaced), *not* including appendices. The body of the text should include primary discussions, important results from the Feasibility Studies and appropriate tables and figures. Detailed supporting technical data, computer output and programs should be included in the Appendices. However, know that material in the Appendix may, or may not, be read, so critical information should not be located there. Also included in the Appendix are CAD drawings of things such as individual components, partially assembled subsystems, perhaps exploded views of sub assemblies and whatever else you feel is needed to clearly convey the details of your mechanical design. A major portion of the Design Team grade comes this draft and not the final submission turned in later. The Design Team will be required to make certain changes in the final submission but this first draft should be their best effort and it is the most important Design Team deliverable in the course. Ideally, no changes to the draft will be required for the final submission. In order to ease the preparation of this document, team members should decide on a uniform means of word processing, so that documents can be shared. E.g. are all documents to be prepared in MSWord or LaTeX? What version of MSWord is to be used? What software will be used to develop figures? Compatibility is the major issue. If everyone is compatible, assembly into a concept Design Proposal is simplified. Also, simply collecting every team members' reports and Feasibility Studies into a Concept Design Proposal produces a very poor document. This document should incorporate the results of all team members, but is has a logical flow and continuity of its own. It is not simply a cut and paste job. All equations must be in a standard mathematical form, i.e. no pseudo equations that look like computer code. Its α not alpha and its k_1 not $k1$. Finally, figures must all be neat and properly presented with axes labeled and units given. See the evaluation form in section 11.

17 Mar., Bill of Materials
During the PDRs of this week each Design Team will present a detailed Bill of Materials. This is list of every part that is going into your prototype includes the name of the vendor, part number and cost of every component, down to the level of the fasteners used.

24 Mar., Layout of all mechanical components
All mechanical components (chassis, shafting, bearings, bushings, shaft couplings, shaft collars, spacers, bearing housings, screws, bolts, nuts, washers, shoulder screws, wheels, tires, links, cables, battery clamps, etc.) are placed on your Design Team's workbench with their respective CAD drawings, and an assembled view showing how they are assembled and fastened together to form the mechanical portion of the prototype. The structural integrity of your design will also be evaluated. An exploded view of your product is beneficial. Only after this deliverable is evaluated may your Design Team proceed with the assembly of your prototype.

26 Mar., Demonstration of electronics, sensors and control logic
All electronics are wired and placed on your Design Team's workbench. Functionality of all electronics (motors, micro-switches, sensors, etc.) and program (control) logic is demonstrated.

21 Apr., Critical Design Review rehearsal
During the week of April 21, during your Design Team's PDR, your Design Team will rehearse your CDR before the Staff and Management of AME40463 Ltd.

21 Apr., Revised Concept Design Proposal
This final version should contain all revisions to the first draft. It should be considered as one of your first professional publications and treated as such. You may want to keep a copy in your personal portfolio, for job interviewing purposes. Each Design Team will submit a single unbound copy of the report, including Appendices.

23 Apr., Critical Design Review (CDR)
This thirty minute formal presentation to Management ans Staff of AME40463 Ltd. as well as the Commissioners and engineers invited from outside the company will take place during the scheduled class period at a location to be announced and it will be videotaped. The presentation **must include quantitative justification for your choices made in designing the system**. It is emphasized that the CDR must demonstrate the quantitative engineering modeling and analysis used to support the design decisions. Videos of prototype performance may be presented. All team members are expected to participate equally in the CDR. See the evaluation form in section 11.

4.3 Details on Squad Deliverables

9 April., Demonstration of individual player and Squad capabilities
In place of regularly scheduled class, both Squads will meet in the Stepan Center. There each Squad will demonstrate the offensive and defensive capabilities of individual players as well as the entire Squad. No contact between players. This is a demonstration of offensive skills such as,

- the ability of the Quarterback to take the ball from the Center
- the ability to complete a hand off
- the ability to throw the ball
- the ability to complete a short pass
- the ability to complete a long pass
- any special defensive capabilities besides hitting.

After this demonstration the Squads should be practicing to prepare for the MFL game.

18 Apr., The Mechatronic Blue-Gold Game
The Blue and Gold Squads will play the first game of the MFL in the Stepan Center. Game begins at 10 am. The Commissioners, AME40463 Management and Staff, your fellow AME students of all levels, your AME Faculty, potential future sponsors and the media may be present.

21 Apr., Blue and Gold Squad Design Team evaluations by Design Team Leaders
Management has provided you with an evaluation form that each Design Team Leader will complete evaluating other Design Teams of their Squad. Careful review of this form at the beginning of the semester will give you a good idea of what is expected of your Design Team and the important issues that will be used by your peers to evaluate your performance during the project. These evaluations are used to determine what percentage of the Squad's deliverables grades are going to be given to each Design Team in the Squad. See the evaluation form in section 11.

21 Apr., Evaluation of prototype mechanics
Management and Staff of AME40463 Ltd. will examine your prototype. The evaluation evaluation form is

included in section 11. In place of meeting in the scheduled classroom, all players will be brought to the Stepan Center.

21 Apr., Evaluation of prototype electronics and programming
Management and Staff of AME40463 Ltd. will examine your prototype. The evaluation form is included in section 11. In place of meeting in the scheduled classroom, all players will be brought to the Stepan Center.

4.4 Preliminary Design Review (PDR) Topic Schedule

Each Design Team will prepare specific items for discussion at each PDR. These informal presentations will take place during the beginning of meeting periods and should include appropriate visual aids or demonstrations. Each Design Team's PDR presentation is limited to fifteen minutes, followed by five minutes of questions and discussions. One or more team members (each team member must participate at least twice during the semester) can make the presentation.

16 Jan.	Design Requirements, Specifications and Constraints.
	Remaining PDR topics will be announced Thursday, January 15^{th}.

5 Feasibility Study Reporting Requirements

The Feasibility Study (due Feb. 10) is one of two major individual deliverables. The actual Feasibility Study will be preceded by the submission of a very brief Feasibility Study proposal (Jan. 27). The Feasibility Study MUST produce quantitative information (numbers) that should be used in assessing the feasibility or characteristics of an important aspect of the proposed concept.

The Feasibility Study proposal is a document of <u>one-page</u> maximum length that should include,
1.) A brief statement of the purpose and significance of the proposed Feasibility Study.
2.) A definition of the design variables, the state variables and the measure of merit.
3.) A list of any constraints on the design variables or the state variables.
4.) A brief description of the engineering analysis or simulation tools to be used in the study.

The Feasibility Study report must contain the following readily identifiable items.
1.) Statement of the purpose/goals of the study. Your Executive Summary (a.k.a. Abstract) MUST begin with the words, "The purpose of this Feasibility Study was to ...."
2.) Detailed description of the information gathered from the engineering models and the analysis performed. Emphasis should be placed on the assumptions made in the engineering models and the resulting limitations. If there is no model that describes how state variables are related to design variables, then one must resort to experiments. This is to be avoided.
3.) Results of the study - graphical are preferred but tables and charts are acceptable if they adequately represent the results.
4.) Discussion of the results of the study.
5.) Brief discussion of the impact of the study on the design and choices made.

The Feasibility Study report is a Technical Report. The entire report should not exceed 12 pages. It should include appropriate graphics. Figures must be presented properly, down to the level of the font size of lettering in the figures.

6 Concept Design Proposal Requirements

Concept Design Proposal is used to document the design of the proposed product. The information that it contains is used to assist in making a decision as whether to continue the product development process. It should be concise, comprehensive and consistent. Effort will be required in the review and editing by all team members in order to produce an acceptable document. It should not be the responsibility of one individual to develop this document and it should not be a mere pasting together of various Feasibility Studies.

The proposal will be evaluated based upon its ability to comply with the following requirements:
1.) A concise description of your proposed product describing desired behavior and characteristics, as well as strengths and weaknesses of the concept. The Executive Summary (a.k.a. Abstract) described below is a key part of the proposal.
2.) Quantitative technical validation of your concept based upon your Design Team's engineering analysis, simulations and prototyping. Various issues will be treated with different levels of detail and your Design Team is responsible for selecting and identifying the most critical issues for your particular design. Your proposal cannot address every issue that could be considered and the selection of the issues to include is an important Design Team decision.

The proposal should include at least the following sections presented in a readily identifiable manner.
A.) Table of Contents
B.) Executive Summary (Abstract) - Stand alone section that describes the product, its intended market and the manner in which it should be used. This section must describe in detail those factors that had the most significant influence on the final design. The discussion must highlight the strengths and weaknesses of the concept and indicate all critical technical, economic or aesthetic issues. It must include visual depictions of the product and might be considered to be a preliminary marketing document.
C.) Proposed Concept Engineering Validation - The Design Team must provide the quantitative engineering justification for their product in these sections. It is not a "how to" nor a "history" of their design activities but details the results of the engineering analysis and simulation used to develop the proposed concept.
D.) Issues related to the next stage in the design process, some attention must be directed towards issues such as materials selection, material processing, manufacturing, assembly, packaging and shipping of the final product in your design proposal.

Appendices:
A.) Appropriate attachments such as competitors' products, information from subcontractors or vendors or supporting technical data (e.g. computer programs, etc.).

The first draft should be submitted on 8.5"x11" paper, printed single sided in a three ring notebook. All pages must be numbered. Figures must be numbered and titled. The final submission must be printed on 8.5"x11" white paper, single sided without hole punches, staples or binding (i.e. loose pages). All pages must be numbered. Appendices are recommended.

7 Engineering Notebook

This is an important individual deliverable. It represents a continuous diary of your activities in this project. This should be a hardbound lab notebook such as you may have used in your chemistry course. The purpose of an engineering notebook is to document the development of this product from your perspective and to help you record your activities and rationale for the decisions you have made.

You should enter into your notebook the date and time of any thoughts or ideas you may develop or perhaps one of your teammates develops. This is the type of information that may prove vital in a patent application development. The notebook may include items such as written text, sketches, flowcharts, timetables, vendors, part numbers, or any other useful information that you think should be included. These notebooks are frequently used to date when inventions were conceived. You may tape information onto pages within the book, but the contents of the book must not fall out. You may fill more than one book and they should be numbered sequentially. You do not need to tape into the notebook information that has been recorded or published in other forms, such as the individual concept study or Feasibility Study. This notebook should represent the notes used to develop those studies. Notebooks will be evaluated weekly then finally graded and will provide an important measure of your individual contribution to this project. The use of engineering notebooks is universal across engineering disciplines. It is a good to develop the habit of keeping one early in your career.

Why a notebook?
It provides a useful reference for yourself and your co-workers and protection and documentation in the patent process.

What goes in a notebook?
Anything you think will be of value. Ideas and thoughts related to the product of the project, preliminary calculations, notes from group meetings, notes from phone conversations (with vendors etc.) along with names and numbers, notes from your review of articles and books, taped in emails, letters etc.

Some formatting instructions.
Bound notebook, not a three ring notebook. Sign bottom of page and date the top of the page as you complete it. A patentable item should be signed and dated by a witness. All entries are in pen only. No blank pages or spaces. Write legibly, if it can't be read, its useless (also will result in a poor evaluation).

email from prior student: *"I just wanted to drop you a line and let you know that I can now appreciate what you guys (Profs. Batill and Stanisic) were trying to get us to accomplish over the course of the semester. I ended up getting a job at Rolls-Royce Allison as a design engineer. The very first day on the job, I was actually handed an engineering notebook pretty similar to the one I used in senior design and I use it everyday."*
1998 ME grad from ND.

8 Comments From Previous Students

At the end of each semester (April 27) students are asked to provide comments for future projects as part of their peer review and course evaluation. The following are some of *their* comments that may prove helpful as you participate in this project. They are not listed in any special order but they do address many aspects of this course and project.
- Do ProE drawings as soon as possible, so you can figure out integration of parts.
- The best course of action is to plan everything out with great detail. Detail on the ProE drawings will greatly improve assembly time, as well as reduce the number of mistakes.
- Build a strong group dynamic from the start, this way communication will improve and ideas will come across and be received better.
- Start and finish one thing, document it well in the design notebook - random numbers mean little without written support. Simplify the problem as much as possible.
- Make your team deadlines fairly and stick to them. Barely anything that you throw together at the last minute is going to work. Make every decision with simplicity in mind.
- Talk to your peers and professors. You can learn much more from a simple conversation than you can from reading a 400-page textbook.
- Make everyone on your team feel important. Everyone has something to contribute, no matter how minor it may seem.
- Be a team player. Remember that this is a team project and that you are a member of a team. Sometimes you have to sacrifice your own goals for the success of the team's goals.
- I'd recommend constantly checking the work others are doing. KEEP IT SIMPLE.
- Get a plan and stick with it. Order parts ASAP. Some take months to get.
- Really think about every decision. Ask yourself 1,000 times why you are choosing A over B.
- Do not assume that black always goes to black and red to red!
- Work as a team and develop good group dynamics early in the semester. It will make the project so much smoother.
- Time management is the key. Do not procrastinate. If you think of something that needs to be done, do it immediately. In this way you should not have to pull all-nighters at all. It is not an impossible project. Just plan ahead and learn to cross the hurdles as they come up.
- Remain open to new ideas and listen to what other people are trying to say.
- When choosing a Team Leader, choose someone you know can do it - not someone who wants to see if they can.
- Have fun. This class is a lot of work, but it doesn't have to be stressful. Having fun makes all the work easier.
- 1)Have fun. 2)Learn from the experience. 3)Take advantage of the opportunity. 4)Be daring in the design. 5)Make your life easy by keeping it simple (yet fun).
- Find as much info about "outsourced" components, material, kits, etc. that are available as soon as possible

so that you can decide what ideas are feasible.
- Don't make up numbers just to meet deadlines - they will come back to haunt you.

9 FAQ's

This course experience is very much unlike most that you have encountered in the past. As you work through this project you may wonder why the course is structured as it is. To help you better prepare for this project and understand the rationale associated with many of the activities in the course, you should review the following. If you have other questions about the project, or want more details on the answers provided below, please ask, as the purpose of this course is to provide you with the most beneficial educational experience as possible. Certain elements of the course have change semester to semester, so direct comparison to past semesters is cautioned.

How does this course fit into the overall ME curriculum? It is the opportunity to tie together a lot of the knowledge and experiences gained in many other course and to apply that knowledge to the design of an engineering system. It should also provide you some insight into the design process - but isn't a course on design methodology as such. There is little new technical information formally presented in this course, though each of you will learn many different things depending upon what aspects of the project you are involved with. Everyone in the course has a different experience and learns different things, depending upon your level of involvement, interests and background. There are many things that can tailor this course to your own interests and goals.

Why not do a real industry project? Is it necessary to do this project as a simulation? Time, support resources and your engineering experience limit the scope of the project that can be accomplished in a single semester. The content of the project and the schedule have been tuned to be consistent with the 14 week semester and every effort has been made to present this project in a fashion consistent with industry practice. In the many years of presenting this type of project and discussing the nature of the course with practicing engineers, we've been told it is very effectively parallels industry practice. In reality the concept evaluation phase for a product of the type considered this semester may not actually be this long, but then you would likely be working full-time on this project alone.

Why are there so many different kinds of deliverables? The project is a simulation of the kinds of activities you will encounter in an actual product development effort. Each deliverable is intended to provide you with an intermediate goal and useful information as you proceed through the project. Every activity should build upon information or decisions associated with previous activities. The key deliverables are the Feasibility Studies, the concept proposal, Concept Design Review presentation and the prototype.

What is the most important thing I should gain from this course? You should improve your ability to make, communicate and justify engineering decisions. And following very closely behind that - you should should improve your ability to work as part of a project team in developing a product with schedule constraints and limited resources.

Why don't you just tell us what kind of product to design? Experience with the earliest stages of the product design process is important and in most cases is the critical point of the product development. This is not a homework problem and you won't find an answer in the back of a book. The project's results will be a reflection of your team and its capabilities.

Why do we each have to propose concept designs if we are are only going to design a few? If each individual brings independently developed ideas to the table as the group begins its development of a concept, then there is a greater chance of a group identifying good ideas that are synthesized from the individual concepts. If the group sits down and discusses ideas before the individuals can do so on their own, you will severely limit the scope and diversity of your team's potential concept. No initial ideas are bad. Some under further review may prove impractical but often it is the combination of features from different ideas that prove most successful. If everyone in the group shows up with the same individual concept, there is a pretty good chance that by discussing your ideas in advance you have eliminated independent thinking and limited your team's options.

Why is the schedule so rigid? To accomplish all the things necessary to complete the major deliverables within one semester, we need to achieve certain milestones along the way. The milestones (along with the academic calendar) define the project schedule. By reviewing the Gannt chart you will see that you don't have much time to complete many of the tasks in the project. No one expects that each of the tasks will be completed perfectly and in all cases it is understood that if you had more time, you could have done more. Keep telling yourself that you are trying to develop and validate a concept for this product, not a detailed engineering solution that would be ready to go into production. Another realistic aspect of the simulation is that just like in the working world, you will never have enough time to be absolutely satisfied with the product you produce.

Why the formal attendance policy? There are a certain number of hours each week when the teams must be all together to communicate, share ideas and review individual progress. Hopefully, much of your detailed engineering will also be done in subgroups so you can have a system of checks and balances and with your very different schedules, finding good group meeting times is almost impossible. The six hours you have together each week, if used effectively, should reduce the need for additional group meetings outside of class. Some of the concerns related to this project taking too much time are directly related to an inefficient use of the class meeting time. By having upper management enforce this policy it also eliminates the need for groups to deal with members who may not be willing to attend regular group meetings.

Why can't we pick our own design teams? You may be able to select the company you work for, but until you are the boss, you will rarely be able to select all of your colleagues. Learning to communicate and work with people who you don't know is an important attribute that you will want to develop. Every attempt will be made to assign teams so that individuals can pursue topics of interest to them.

What happens of I don't like some of the members of my team? See the answer to the question above. You will need to separate your personal opinions from your professional behavior. Understand that all students have different goals and personalities and that you may learn more about yourself as you deal with others. Developing good people skills, as well as tolerance and understanding will be worth the effort.

What happens if I really have a problem with someone in the team? See management before a small issue creates problems that will be hard to overcome. Keep in mind that everyone is under considerable stress and subjected to very demanding workloads. Try to deal with internal differences as professionally as you can but if you feel that you are unable to, see you instructor and all discussion will be kept in the strictest confidence.

Why all the emphasis on Feasibility Studies? This study (although it takes on different names such as a Trade Study) is fundamental to the process that engineers use to assist in making and justifying engineering decisions. Often you will have to estimate or make a good guess in order to make some of the decisions required or at least to get a start on converging to a good decision. Some decisions will be based upon your experiences or that of others but some must come from, and be substantiated by, engineering modeling, analysis and simulation. That is what makes engineers different from hobbyists and hackers who work in their garages. You will only have time to study select areas, so part of the challenge is to identify critical areas where your efforts have the highest payoff or reduce critical risk factors associated with your concept. Your time is your most valuable resource. Do not waste it. After you leave here you will find that people will require you to justify your decisions and this will help you figure out how that is done.

Why do we need to write a proposal for our Feasibility Study? This will help you and management determine if you have selected a reasonable topic for your study. Since this study is a major element of your grade (and for one of the few time in your academic career you will get to "ask the question" that needs to be answered) you will want to be very careful not to attempt an ill-posed study, or one that is too difficult to answer in the time allotted. The Feasibility Study proposal is part of the overall project planning process and will help the group determine how its people/time resources are being used.

Why do we have to keep a formal engineering notebook? The process of documenting your engineering activities in the form of a notebook or journal is required by many organizations. The notebook will help you keep track of who is doing what, when to meet again, what you are responsible for, why you made a particular decision weeks ago, what you are responsible for, etc. Developing some experience and good work habits in this area will prove useful for years to comes.

Why is this course only one semester long? We could extend the projects for two semesters, or more, but there are so many other issues related to your academic schedules that this would create many additional problems. This question is often the result of students concerned about how the final prototype functions and their concern is that if they had more time, they could get more done, and they would be sure it would work. Success in the course is not solely dependent on the performance of the prototype but also in your ability to achieve progress in the major learning objectives of being able to make and justify engineering decisions and being able to work as part of a project team. It doesn't take two semesters to achieve those goals. However, know that a poor prototype is typically a product of poor engineering and unsound decision making. If your team's prototype is not very successful, be sure to note where the errors in the process occurred and avoid those errors in the future. Remember, much learning comes by failure and a particular error in judgment is not a mistake, unless you repeat it. Learning is a self-correcting process, not necessarily associated with high or low intelligence. Its a matter of either learning or be eventually being eliminated, a sort of intellectual evolution!

Why does this course take up more time than some of my other courses? Due to the very open-ended nature of the projects - there is no right answer - thus there is a tendency on the part of students not to know when to quit. Also, due to lack of experience in projects of this scope, often students do not plan their time effectively and leave certain decisions and activities until the last minute. One of the biggest source of problems in this area comes from an individual or team not devoting adequate time to the early phases of the project. If you make a somewhat arbitrary and often last minute decision, early in the project, you can end up making large time consuming (and many time unsolvable) problems later on that could have been avoided. The expectation is that you devote consistent and reasonable effort to the project and present the results achieved. Not every group will achieve the same level of success with the same level of effort and this should be recognized. Look at how other teams are working, both well and not so well. Learn from that. Individually you need to decide how much effort you want to expend and then communicate that to your group. Do not assume responsibilities or make commitments that you cannot satisfy. Be honest.

Why this particular project? Potential projects are judged on a variety of characteristics. In the last few years it has been one of the course goals to provide projects that have embedded intelligence and a degree of autonomous operation.

We do not have to manufacture the actual product so should we be concerned with issues related to manufacturing and assembly? Very definitely. You will not carry this project on into the detailed final design and manufacturing stages but you must consider these issues in your design. You will need to include sections related to materials selection, material processing, manufacturing, assembly, packaging and shipping of the final product in the Concept Design Proposal. The feasibility of the overall product depends upon more than just the functional behavior of the prototype. The level of detail that you can provide in each of these areas depends upon your concept, experience, knowledge and where you place emphasis in the project.

What is the purpose of the Peer Review? Throughout your career you will be evaluated on a variety of skills and attributes - many of these assessments will be very qualitative. you will also be required to make objective assessments of peers and subordinates. The peer review - particularly if you think a bit about it as the semester progresses - will also begin to help you understand how others may view your performance as an engineer. Do you listen, how effectively do you meet deadlines and communicate your ideas to others, etc. Just as you will review others, you will be reviewed and that is something to keep in mind. Lastly, upper management uses this information to decide how to fairly distribute credit for the collective Team Deliverables which make up 50% of your final grade.

What role will CAD software like ProE play in this semester's project? A critical role. Your digital model of the prototype should include a level of detail down to bolts, washers and nuts. If it doesn't fit together in your digital model, it won't physically either. You also need the digital models to communicate to others in the team exactly what and how things are to be manufactured. Outsourced parts should also be modeled so as to see how they fit into an assembly. ProE may very well be one of your most important tools, here and in in your future career as an engineer.

When can we begin the prototyping process? This is not a "cut-and-try" engineering project. That does not work in this time frame. As soon as you feel you have properly engineering a component or subsystem and it integrates with the system as a whole, fabricate it. But be sure it is truly is engineered properly, or you will be wasting a lot of time manufacturing it,or funds purchasing it, causing significant problems down the road. You have a limited budget and it is important you get your hands on the hardware early in the semester (first thing!) so you can develop some experience with the sensors, actuators, micro processors, machine tools and CADCAM software early on and learn their capabilities. In fact, in the concept development a knowledge of these is necessary. See Mr. Brownell as soon as possible and see whether your ideas for sensors, and how they will be used, is possible. Find out about as many different types of sensors as you can and their compatibility to other components. Get certified on the manufacturing machinery. Browse through parts catalogs, such as Allied Devices, Berg, Small Parts Inc., and mostly McMaster-Carr and see what types of machine components are available from vendors. Get on the Internet and use the Thomas Register to search for parts. These things need to be done in the first seven days of the project, otherwise your concepts will be ill-based.

Why is the Concept Design Proposal due before the end of the semester? The draft version is due at the point in the semester when the design process should effectively be finished and you primarily involved in completing prototyping, but most importantly in testing your prototype. By submitting a draft before the Critical Design review you are allowed some time for reflection and feedback from management. It also gives the time to complete this important deliverable before the rush of activities that takes place at the end of the semester. With the proposal completed, preparation for the CDR is very easy as you have already developed the figures and data and it is now merely a matter of how you are going to present this knowledge and explain it to the reviewers. Though this is a draft, if you are careful and submit a complete and professional document, you will not need to spend a significant amount of effort completing the final version.

Why are the "locked down" tools in B-19 available for limited times All equipment in B-19 must be used with some care. We have worked very hard to be certain that there are no injuries and that students use the equipment properly. The locked down equipment must be used under supervision and there are limited times when that supervision is available. These are particularly dangerous machines. From the beginning of the semester each team should use the regular class meeting sessions to develop the necessary skills to operate these machines. You will have to be certified on their operation and be prepared to show your certificate when asked. Do not attempt to use the machines without certification, it is a violation of the safety rules to do so.

Why do we have weekly PDRs? They provide an opportunity to develop your presentation skills as well as identify key issues during the project. It also gives everyone practice at both asking and answering impromptu questions. Many of the questions in traditional classes are "how did you do this" and in this course they are more of the "why did you do this" nature. Also, we will all learn from you as you make your presentations, thus sharing knowledge. Finally they will help prepare you for your CDR where you will present to group of professional engineers from industry and at that time you will want to be prepared and have a certain level of self-confidence. It is much better to practice in front of "family" than in front of a potential employer.

Why do you keep answering our questions with questions? The key goal here is to develop your ability to make decisions and the role of upper management is to ask questions to assist the students who are ultimately responsible for making the decisions. Management will not make decisions for you. We will provides facts, when we can, and help troubleshoot, but the eventual responsibility for all decisions made in the project depend upon the engineers (the students).

Why do we need this ridiculously large course handout? This project is different from other academic experiences you have had at ND. You need somewhere to go to gather information on the hows, wheres and whys for this project. This handout should be considered an employee's manual. You need to review it carefully at the beginning of the semester to understand what is expected of you and how and where to get it done. Hang on to it and refer to it as the project progresses.

Why avoid using the word "hope" or any derivative of it? "Hope" is for matters of religion and romance only. Use of this word is a red flag indicating that either you lack the understanding of an important aspect of your design, or you are disregarding it. Either one is not a good thing and is sure to get you in trouble during the design process. If you use this word that is dreaded in engineering, you are at best guessing without verifying and you will likely pay the price for that. You will be "down-sized" at the first opportunity. Use the engineering skills that you have. If you do not have the skills, admit it and accept your ignorance and failure to learn the modeling tools when they were presented to you. Then, learn the engineering tools you need (self learning) and ask for guidance from senior engineers. Eventually, you will engineer correctly. In engineering, hoping will only lead to disaster. It is unethical.

10 The Squads and Design Teams

You have been organized into the following Squads and Design Teams.

Blue Squad

Team B1 (Programming): Allen T., Valenzuela A., Ouimet M., Beall M.

Team B2 (Electronics): Storey M., Byrne C., Wells J., Rave D.

Team B3: Devitt B., Heye C., Zanghi D., Byrne C., Petrongolo M.

Team B4: Barrera J., Baker T., Skinner C., Vignali P.

Team B5: Sudyk M., Young M., Helffrich R., Krause C.

Team B6: Jackson S., Linnemanstons J., Carley J., Hommes P., Castillejo J.

Team B7: Lechner L., Slaboch B., Lombardi A., Kostka K., Palomo R.

Team B8: Bartrom J., Fralish J., de Groot S., Silva L., Behrens D.

Gold Squad

Team G1 (Programming): Branham J., VerHulst C., Yanchak N., Nakatsukasa L.

Team G2 (Electronics): Parry J., Macke E., Springer N., Schlueter P.

Team G3: McLeod W., Soltis J., Furlong T., Hall M.

Team G4: Stuart W., Toates E., Lashmit H., Voll P.

Team G5: Jaffa N., Kargol E., Hamamoto, B., Menold A.,

Team G6: Lorico A., Haas L., Romero Montoya C., Kron K.

Team G7: Shinnick T., Glees D., Wilson K., Brodfuehrer A., Gonzales K.

Team G8: Seibel, D., Creasy K., Galbraith M., Schaller D., Henkel T.

11 Attachments

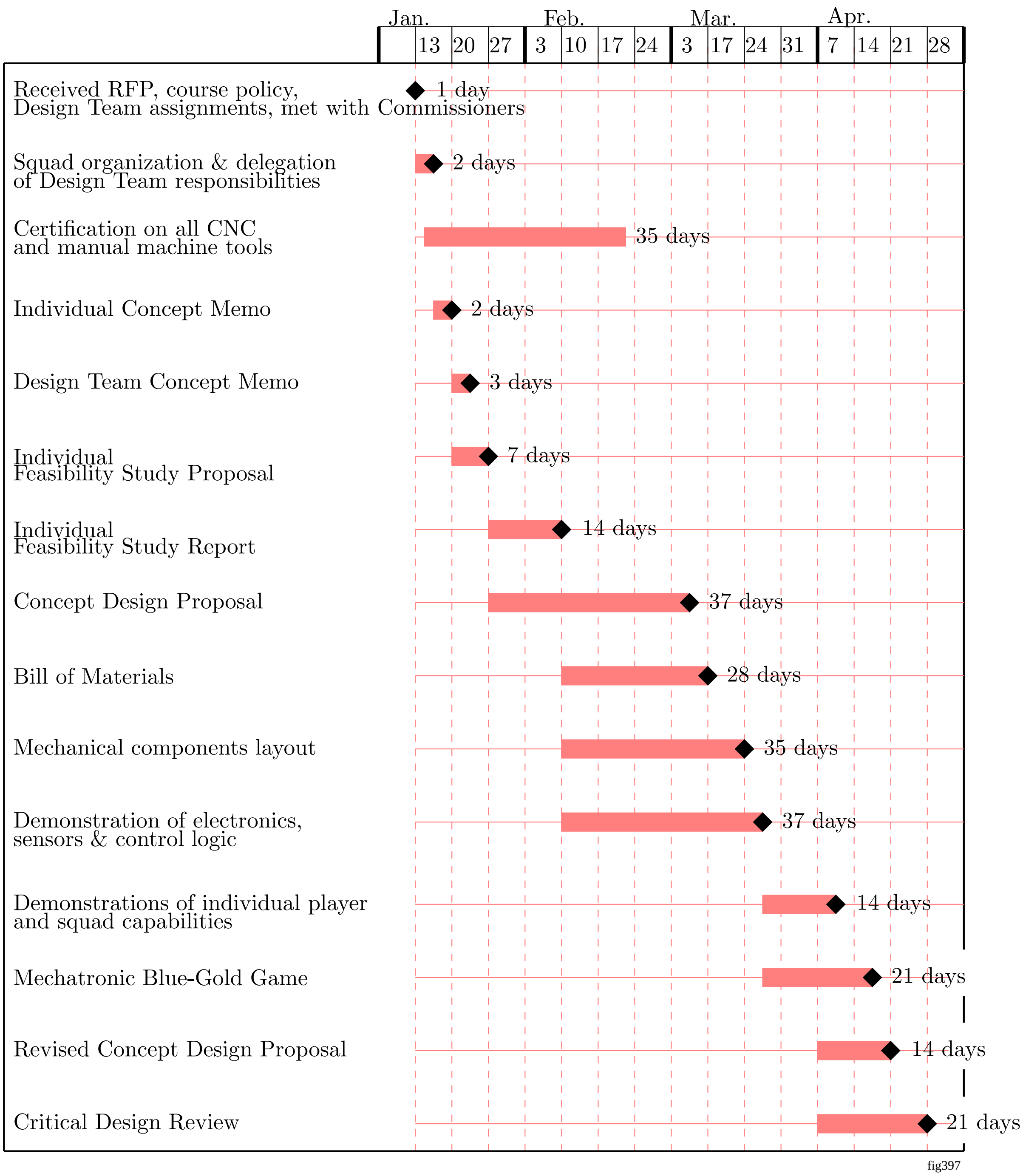

Figure 1: Project Gantt Chart

Individual Concept Memo Evaluation Form

Engineer:	Score:	
		(20 max)
Written explanation of basic characteristics.		6 pts.
Sketches - subsystem drawings - quality, detail and scale.		7 pts.
Description of strengths and weaknesses of concept.		7 pts.

Feasibility Study Proposal Evaluation Form

Engineer:	Score:	
		(35 max)
Statement of the purpose of the study.		5 pts.
List of design variable(s).		5 pts.
List of any constraints on the design variable(s).		5 pts.
List of state variables.		5 pts.
List of any constraints on the state variable(s).		5 pts.
Description of the modeling and analysis tools to be used in order to determine the state variable(s) that results from a given design variable(s). Using a simulation package such as ProMechanica for this purpose is a sure sign that you do not know what you are doing.		5 pts.
Measure(s) of merit. Generally the measure(s) of merit comes from a Merit Function(s). These take a great deal of time experience to develop. You will probably not be able to. So, how are you going to measure the merit?		5 pts.

Feasibility Study Evaluation Form

Engineer: Score: (53 max.)

1. Abstract ______

0-no mention of purpose
1-purpose implied but not explicit
5-purpose stated but not specific or useful to assess role of study
10-clear statement of purpose and anticipated influence of study, design and state variables given, and basic results reported.

2. Defines design variables (DV) and any appropriate limits (constraints) on the DV ______

0-no mention of design variables
2-general list of potential design variables (no limits or bounds)
3-explicit statement of DVs and associated limits, but misused or not used in study
4-explicit statement of DVs and DV limits, only some used appropriately in study
5-explicit statement of DVs and DV limits, the appropriate use of each

3. Defines state variables and any appropriate limits (constraints) that describe the design ______

0-no mention of state or behavioral variables that describe system's performance
1-some statement of state or behavioral variables
3-description of state or behavioral variables but no indication of limits or constraints
5-effective description of important state variables and any constraints on them

4 Description of tools or methods used in the study ______

0-no mention of analysis tools or models upon which they were based or unnecessarily resorts to the use of a simulation package
3-vague description without details that would allow process to be duplicated
6-effective description of method of analysis without source references, validation or benchmarking
10-effective description of models and methods, references when necessary and validation of methods

5. Measures of merit or some means to differentiate between design choices ______

0-no mention of merit or means to differentiate between competing designs
1-some statement of merit but no effective use in Feasibility Study
3-multiple measures of merit and no indication of how to use them
5-effective statement of a useful means to differentiate between competing designs

6 Presentation of the results ______

0-no explicit presentation of results from analysis, simulation
or used alpha instead α or k1 instead f k_1 or no units
on axes or figures are too small
or other information sources
2-presented only "raw data" or data without appropriate units, legends,
supporting information
4-excessive data (but correctly presented) that is not used to support decision
6-concise tabular or graphical presentation with labels and
legend that support results

7 Discussion of the results ______

0-no discussion
3-general discussion of the results but no attempt to identify
key design variables or states
6-some use of merit or constraints to differentiate designs but
identification of key issues left to reader
9-concise discussion that highlights key issues and references to
quantitative results from analysis

8 Discussion of the influence of the results ______

0-no mention of impact of study on current design
1-some attempt, but unable to identify how the design was influenced
2-indication of impact but no justification based upon information
included in the study
3-concise statement of influence study (positive or negative)
and quantitative validation

9 Overall presentation of study ______

0-lacks format, organization or structure
or incorrectly presented mathematical formulas (e.g. k1 instead of
k_1 or alpha instead of α)
1-some structure but "fluffy" text and vague descriptions
of key issues or poor proofreading
3-reasonable structure, effective written text, inadequate
proof reading, not concise, too long
5-appropriate for review at higher levels of the organization

Engineering Notebook Evaluation Form

Engineer:	Score:	(40 max)

Consistent entries	10 pts.
Professional presentation	10 pts.
Content	
Engineering content	5 pts.
Organizational material and meeting or discussion notes content	5 pts.
Effective sketches and schematics with explanations	5 pts.
All entries dated	3 pts.
Entries in pen	2 pts.

Concept Design Proposal (first draft) Evaluation Form

Team Name:

The following is NOT an outline of the sections in your Concept Design Proposal.
These are the various aspects of your proposal I will be evaluating.

Executive Summary — 40 pts.

- -"standalone" section
- -describes basic product, key characteristics and typical operation
- -tabular summary of key Product Specifications and Constraints
- -details those factors which had the most influence on the design
- -strengths and weaknesses of the design and indicates all critical technical issues
- -appropriate assembly drawing/s or 3-view drawings

Detailed description of the quantitative requirements and target specifications (of product, NOT of project!) — 20 pts.

- -includes evaluation of each phase of the product's use
- -provides quantitative targets when appropriate

Concept selection — 20 pts.

- -detailed discussion of all appropriate competing concepts considered for subsystems
- -sketches of each concept required-NOT to be identified with individual engineers
- -table that state the specific strengths and weaknesses of each concept considered
- -Design Team concept justification (compared with the other concepts considered)

Operation and automation — 25 pts.

- -basic operation
- -hardware requirement (sensors and actuators)
- -complete circuit drawing for all electrical systems and components

Basic chassis — 15 pts.

- -description of components and interfaces
- -mechanical loads/stresses, deformations and margins of safety

Internal Mechanisms; force-torque transmission and positioning issues — 15 pts.

- -descriptions of components
- -estimates of loads, stresses, deformations, margins of safety
- - materials selection and justification
- -mechanism analysis (kinematics)

Appendices: (Not included in 75 page limit)

Digital (CAD) models of all parts and assembly drawings	120 pts.
Feasibility Studies (NOT identified with any individual)	10 pts.
Other technical attachments deemed appropriate by Design Team	0 pts.

Grading Summary:

Content Score (135 pts. max.) ______

Appendix Score (130 pts. max.) ______

Presentation Score (40 pts. max.) ______

- Organization (10 pts.)
- Consistency and style (10 pts.)
- Graphics (10 pts.)
- Overall Quality (10 pts.)

CONCEPT DESIGN PROPOSAL SCORE (305 pts.) ______

Evaluation Form for finalized CAD

Team: Score:

(280 max)

Not merely a concept (120 pts.) ______

Appropriate use of Fasteners (20 pts.) ______

Manufacturability (20 pts.) ______

Appropriate use of Outsourced Parts (20 pts.) ______

Appropriate Mounting of Bearings (20 pts.) ______

Appropriate Shaft Couplings and Hardware (20 pts.) ______

Appropriate Shafting (20 pts.) ______

Appropriate Shaft Supports (20 pts.) ______

Appropriate Packaging (20 pts.) ______

Inappropriate use of Glue, Epoxy, Tape, Wire, etc for Part Joining (-20 pts.) ______

Evaluation Form for Prototype Electronics and Programming

Squad:	Score:
	(200 max)
Use of a Wiring Harness (20 pts.)	______
Integrity of Wiring Connections (20 pts.)	______
Thoroughness of Schematic Diagram(s) (20 pts.)	______
Appropriateness of Power Sources (20 pts.)	______
Quality of Motor and/or Servo Control (20 pts.)	______
Appropriate Selection of Controller(s), Motor(s) and Servo(s) (20 pts.)	______
Appropriate Choice of Sensors (20 pts.)	______
Program Structure (have your programs with you) (20 pts.)	______
Effective Code Commenting (20 pts.)	______
Functionality of Electronics and Controls (20 pts.)	______
Questionable Wiring Practices (-20 pts.)	______
Component Failure or Burned Circuits (-20 pts.)	______

Evaluation Form for Prototype Mechanics

Squad:	Score:	
		(200 max)
Appropriate use of Materials (20 pts.)		______
Appropriate use of Fasteners (20 pts.)		______
Quality of Part Fabrication (20 pts.)		______
Appropriate use of Outsourced Parts (20 pts.)		______
Overall Structural Integrity (20 pts.)		______
Appropriate use of Bearings (20 pts.)		______
Appropriate Shaft Couplings (20 pts.)		______
Appropriate Shafting (20 pts.)		______
Appropriate Shaft Supports (20 pts.)		______
Appropriate Packaging (20 pts.)		______
Use of Glue, Epoxy, Tape, Wire, etc for Part Joining (-20 pts.)		______
Component Failure (-20 pts.)		______

Critical Design Review Evaluation Form

Reviewer:

Design Team Name:

1. Overall organization of the presentation (10 pt.) _______

2. Ability to describe the product, key features and operation (10 pts.) _______

3. Ability to effectively convey reasonable confidence, as engineers, in the technical feasibility of the product (10 pts.) _______

5. Effectiveness in answering questions (10 pts.) _______

TOTAL (50 pts.) _______

Preliminary Design Review Evaluation Form

Presenter:

Design Team Name:

1. Effectiveness of Visual Aids (20 pts.) ______
Lettering size is appropriate
No use of "gimmicks", such as spinning slides etc.
Colors are visible on the screen (try to use very dark letters and white background)
Presentation is not to long (recommend one slide per minute MAX)

2. Speaker conveys confidence (20 pts.) ______
Speaks to all Squad engineers, not just AME40463 Management and Staff
Seems comfortable
Looks at audience
Is prepared

3. Presents QUANTIFIED information (20 pts.) ______
Does not use the word hope

4. Presenter is prepared (20 pts.) ______
Presentation is dense
Starts on time
Stops on time

5. Quality of Discussion (20 pts.) ______
There is none because nobody gets it or nothing is really presented.

Total (100 pts. max) ______

AME40463 Mechanical Engineering Senior Design
Confidential Design Team Peer Evaluation Forms
and Course Evaluation

This portion of the course packet is for the purpose of, your evaluation of the contributions of your other Design Team members towards your Team's product development. he Evaluation Form to be filled out by each member of your Design Team. The information will be used to distribute amongst the members of your Design Team the points that were earned by your Design Team. This will contribute to 50% of your final grade. The other 50% of your grade comes from your Individual Deliverables. Your Individual Deliverables were the items followed by the symbol (ID) in section 4.

This evaluation is an important experience for you and key element in the instructor's evaluation of your fellow engineers. All evaluations are strictly confidential and are delivered to Professor Stanisic in a sealed envelope with your name, your Design Team's name and your Squad's name on the front. You will be evaluated on your ability to provide effective evaluations of your team members. Please consider each item carefully.

Rate each member of the Design Team (not including yourself), in each category. For each category (i.e. column) you have 30 points to distribute amongst your three Design Team members, if you were in a Design Team with four members. If you were in a Design Team with five members, you have 40 points to distribute amongst your four Design Team members. You are also asked to provide brief handwritten comments about each Design Team member.

In order for you to receive a grade for this course, you must submit this evaluation. Place the evaluation in a sealed envelope and return it Prof. Stanisic on the last class meeting on Tuesday April 28 at the start of the class meeting. Include the comments to future students in your envelope please.

Name of Evaluator:

Name of Design Team:

Category	1	2	3	4	5	6	7	8	9	10
Engineer's Name										
1										
2										
3										
4										
Column Total (Column Total)	30 (40)	30 (40)	30 (40)	30 (40)	30 (40)	30 (40)	30 (40)	30 (40)	30 (40)	30 (40)

fig398

Categories:
1. Technical ability
2. Written communication skills
3. Oral communication skills: listening and speaking
4. Willingness and ability to work with others in the Design Team
5. Ability to adapt to new ideas
6. Willingness and ability to contribute ideas
7. Level of overall effort
8. Compliance with Design Team deadlines
9. Contribution to product design
10. Contribution to hardware development

1. Engineer's Name:
Comments:

2. Engineer's Name:
Comments:

3. Engineer's Name:
Comments:

4. Engineer's Name:
Comments:

If you could offer **ONE** piece of advice to someone who will be taking this course in the future, please do so below.

The following items are the objectives set forth for this course and described to you the first day of class. Please indicate your response using the traditional A to F grades (you can use + and - if you want) whether these goals were achieved to your satisfaction.

1.) It was an experience that required active student participation.

2.) It enhanced my skills related to engineering design methodology, including modeling, simulation and Feasibility Studies.

3.) It fairly represented the mechanical engineering design process.

4.) It illustrated the interaction between competing technical and non-technical issues and the role of compromise, constraints and merit.

5.) It provided exposure to various phases of the design process, from requirements definition to product realization.

6.) It helped develop an understanding of the planning, coordination and communication required in a team effort.

7.) It allowed me to be innovative.

8.) I was able to apply my skills to areas of my particular interest.

This was the capstone experience in the mechanical engineering curriculum at the University of Notre Dame. We attempted to present an academic experience providing the greatest benefit to you as you begin your professional career. Please provide any comments related to the course, its organization, presentation, facilities, etc., which you think would benefit future students of this program. Feel free to use the back of this page.

AME40463 Mechanical Engineering Senior Design
Confidential Evaluations of Design Teams by Team Leaders

This portion of the course packet is for the purpose of, your Team Leader's evaluation the contributions of the other Design Teams towards your Squad's product development.

Squad Name:
Team Name:
Name of Team Leader making this evaluation:

Rate each Design Team (not including yours), in each category. For each category (i.e. column) you have 70 points to distribute amongst the seven other Design Teams in your Squad. You are also asked to provide brief handwritten comments about each Design Team. Place the evaluation in a sealed envelope and return it Prof. Stanisic on the last class meeting on Tuesday April 28 at the start of the class meeting. Name of

Design Team: (E.g. G5. See section 10 for Design Teams)

Category	1	2	3	4	5	6
Team's Name						
1						
2						
3						
4						
5						
6						
7						
Column Total	70	70	70	70	70	70

fig399

Categories:
1. Integrity of the Design Group's product
2. Design Group's communication
3. Willingness and ability to work with other Design Teams to integrate products.
4. Level of overall effort
5. Compliance with Squad's deadlines
6. Overall contribution to the development effort