2.75 (G), 2.750 (UG CI-M) Precision Machine Design - Fall 2011 Syllabus

Syllabus updated 4 October 2011

Prerequisite: 2.72 or machine elements experience, Units: 3-4-5

This course provides intensive coverage of precision engineering theory, heuristics and applications pertaining to the design of mechanical systems. Topics include: economics, project management and design philosophy; principles of accuracy, repeatability and resolution; error budgeting; sensors; sensor mounting; systems design; bearings; actuators and transmissions; system integration driven by functional requirements and operating physics. Students will work in small teams to execute a substantial term project with emphasis placed upon developing creative designs, via a deterministic design process, which are optimized by analytical techniques. This is a communication intensive course.

This year's course will offer term projects in two critically important fields: Medical devices & Energy harvesting and conversion devices.

Teaching Staff

Instructor-in-Charge	**Graduate Instructor**	**Teaching Instructor**	**Communication**	**Administrative Guru**
Prof. Alex H. Slocum	Nevan C. Hanumara	Nikolai Begg	Dave Custer	Deborah Alibrandi
Room 3-445	Room 3-470	Room 3-470	Room 24-611	Room 3-438 (9-13:00)
Phone: 253-0012	Phone: 258-8541	Phone: 258-8541	Phone: 253-7787	Phone: 253-2883
slocum@mit.edu	hanumara@mit.edu	nikolai@mit.edu	custer@mit.edu	deborah@mit.edu
Mentor	**CIMIT & Clinical Advisor**	**Mechatronics Advisor**		
Julio Guerrero, PhD	Dr. Rajiv Gupta, PhD	Harrison Chin, PhD		
Schlumberger Research	MGH Radiology	Room: 1-004A		
jguerrero1000@ gmail.com	rgupta1@partners.org	Phone: 258-5742 hchin@mit.edu		

Website: **http://web.mit.edu/2.75/**
Lecture: **TR 3:00 pm – 5:00 pm** **Room 3-442**

This class seeks to emulate real world product development effort, and in a professional fast paced R&D team there is no room for excuses. Attendance is thus highly recommended at all lectures: Blank looks when issues are raised in design reviews indicate the student was not in lecture/not paying attention/not doing the reading and will be reflected accordingly in the student's grade. Generally lectures will be split into two halves with a 5 minute break between. Nominally, Tuesday lectures will focus on FUNdaMENTALS and Thursdays offer guest lectures on clinical and energy topics. Lectures will also include three in-class presentations.

Special Sessions may be offered Friday afternoons; these will include one or more highly recommended visits to local companies.

Team Project

Students will work in small teams to execute a substantial term project on a medical or energy topic.

The goal of the class project is to work with a client to rapidly and efficiently develop a proof-of-concept prototype device which addresses a real need. Prototypes are demonstrated during the final presentation and documented in a written paper.

The project lasts the entire 14-week semester and is roughly broken up into thirds:
1. Problem presentation by client, team formation and detailed problem investigation/understanding
2. Development of strategies, concepts and detailed engineering
3. Fabrication, testing, modification and presentation

Possible project topics will be presented the second week of class and attendance at the project presentations is mandatory.

Project sign-up will begin after the presentations. Students will be asked to indicate their primary and secondary choices and self-formation into teams is encouraged. Teams will be sized 3-5 people and staff will facilitate their formation. Given the wide array of student interests and expertise there have been few difficulties in the past satisfying everyone.

Please understand that given the clinician-client, small teams and aggressive schedule signing up for a project constitutes an implicit agreement NOT to drop the class. Because full participation in the project is integral to the class listeners, unfortunately, cannot be accommodated.

Teams will follow a deterministic design process which fosters creativity, but eschews shoot-from-the-hip design. Decisions will be backed up by appropriate analysis and PREP – *Peer Review Evaluation Process*. Teams will, firstly, study prior art and develop a clear understanding of the problem and the solutions' desired functional requirements (FRs). Then they will work towards developing strategies and concepts of meeting the (FRs). Bench-level prototyping and testing will be conducted. Prototype design will be broken into modules, which are addressed in order of criticality, and then integrated into the final working device.

Weekly Team Meetings

Weekly one-hour team meetings for each team will be arranged with the course staff to review progress and brainstorm/solve project design problems as well as locate resources. It is critical that for each meeting, each student brings their design notebook which has been peer reviewed by teammates *before* the meeting!

Teamwork

Team work is central to functioning of this class and any modern engineering endeavor and it is expected that students will work together in a safe, professional, and collegial manner as defined in MIT's policies and procedures, especially 9.0 "Relations and Responsibilities Within the MIT Community," http://web.mit.edu/policies/9/. During the first weeks of team work, identify problems with your team's dynamics promptly, document them, bring them to the attention of your team members and/or course staff, and defuse them (the problems, not the team or the staff...) using the best diplomatic practices available to you. Team building will be highly emphasized and supported by the Gordon-MIT Engineering Leadership Program (http://web.mit.edu/gordonelp/).

At the end of the course team members will have the opportunity to formally review each other and your combined ratings can be used to adjust your grade by up to a full letter. A mid semester peer review will be conducted and used to provide team members with anonymous, constructive feedback. (This will not affect your grade.)

Lab

In addition to the project, there will be a single multi-week lab assignment to help familiarize you with shop tools and equipment and practice material from the lecture and the readings, so that you can succeed with the project prototype. The lab assignment will culminate in a device, a short written report and a public demonstration.

Prototyping

Teams will have a budget of about $4K prototyping and testing their solution. In general, this can be used for purchasing components and manufacturing parts. Legitimate expenses include: components, machine shop services (must get an estimate for cost of job), local travel (mileage), etc. Food is not covered. Deborah Alibrandi will administer team accounts and oversee purchasing procedures and guidelines. Ask the course staff if there are any questions.

Many teams will want, particularity during the initial project stages, to fabricate their own parts: Available resources include:

MIT Hobby Shop - Safety training and membership required (fee can be a budget item)
Edgerton Center Student Shop (44-023) – Safety training required
LMP (35-231) – For Mechanical Engineering graduate students
Pappalardo Shop - Best times are in the morning

Students often prefer, with the permission of their advisor, to use their own research labs. Limited lab bench space and tools for assembly and testing can be provided in 5-007 or 3-438; teams are responsible for keeping the workspaces clear and returning equipment to the proper storage otherwise access will be revoked. Since each project is different staff will work individually with teams to ensure that they obtain the necessary resources.

Note: At no time can animal tissue be used in non-bio workspaces.

If there are any questions / doubts regarding fabrication or safety please ask the course staff.

Documentation

Students are expected to maintain lab notebooks with sketches, calculations, pasted in pictures, etc, which are informally reviewed during meetings and factor into grading, however their primary function is to document the design process, especially with regards to building a design history file and establishing inventorship. The instructors also keep notebooks which they updated during meetings and presentations and use them to manage the teams and document their own contributions.

Other documentation, in addition to the design notebook, should be posted to the class (secure) Wiki which will document the development and progress of your project. This Wiki will be viewable by other teams and the staff and will be consulted during class.

Teams will write a publication quality final paper, which they are then encouraged to submit to a conference or journal; many have been selected for publication. Write early and write often: It is critical to document (write) as-you-go and in order to prevent teams from waiting until the last minute, sections of the paper will be due through the course and posted to the Wiki. Therefore, ideally by the end of the semester only editing will remain. In addition to the paper, teams will be expected to turn in their PowerPoint presentations and a 1 page project description.

Intellectual Property

IP is often generated in this course, and thus it is essential that all team members (clinicians and instructors included) keep bound, signed, dated and witnessed design notebooks to record individual contributions. Not everyone will necessarily be an inventor, but the more engaged a team member is the greater the likelihood that he or she will contribute specific features (claims) to the IP and, thus, be formally considered an inventor. Whether or not you are an inventor has no effect on your grade, because you can be a person who reduces an idea to practice. IP and any royalties will be shared amongst the inventors and their institutions. IP created by students in an MIT course is considered property of the students; however it may be assigned to the MIT Technology Licensing Office for prosecution.

Communication

2.75 is a graduate course that requires students to communicate as professionals (weekly design reviews and a term paper of journal quality). 2.750 is a CI-M course for undergraduates and hence requires significant development of communication skills, which is also excellent professional practice for graduate students. The communication requirements for both graduates and undergraduates are the same and fun and exciting, because they are all in the context of the team's project. They include:

- Weekly peer review of each other's work in design review meetings (with the instructors meeting the teams).
- 20 minute presentation by the team to the class of top solution strategies ("best" selected if possible).
- 20 minute presentation by the team to the class of top solution concepts ("best" selected if possible).
- 30 minute final presentation by the team to the class, clinicians and invited visitors
- The team is responsible for submitting a final report in the form of a journal article suitable for the ASME Journal of Medical Devices or ASME Journal of Mechanical Design. (Recommended: 20 pages double spaced plus figures; details go in Appendices.) An "A" grade project is one that is presented in form and content that is actually ready to be submitted to a peer-reviewed journal. *Most of the final reports are either published in a journal or at a conference and a patent application may be filed*.

Following the final presentations and filing of any patents that may be required, final deliverables (or a subset thereof) may be posted to the course website to serve as a record and example for future teams.

Course e-mail lists

Students agree that these e-mail lists will be strictly limited to course use only.

2.75-2011	Contacts the entire course students and staff
2.75-staff	Contacts the course teaching staff

Teams are welcome to create their own internal e-mail lists with or without their client; if you do so please post them to the Wiki.

Recommended Texts

1. Slocum, A. H., Precision Machine Design, © 1995, Society of Manufacturing Engineers, Dearborn, MI
   Order direct from the Society of Manufacturing Engineers www.sme.org (Identifier: BK92PUB5, $125.60 including shipping) or www.amazon.com ($112.00 with free shipping).
   If one dozen students agree to buy the book we will bulk order them for ~$70 each.
2. Free Online Text: FUNdaMENTALS of Design by Prof. Slocum posted to the course website.

Incredibly useful handbooks every practicing design engineer should own:

1. Machinery's Handbook, Industrial Press, NY, NY
2. R. J. Roark, W. C. Young, Formulas for Stress and Strain, McGraw-Hill Book Company

Grading

The course grade is based on: A = 90-100; B = 80-90; C = 70-80

Term project (team grade, based on execution of the design process)	
Quality of design (design and execution)	40%
Team performance	5%
Communications	
4 Presentations	20%
Biweekly progress report / section drafts posted to Wiki	5%
Weekly lab notebook (peer) review	10%
Lab (Kinematic Coupling)	10%
Peer evaluations from teammates	10%
Total:	100%

Fall 2011 Schedule

Please note that schedule may be modified as circumstances demand during the course of the term.

Wk #	Start Date	Tuesday 3:00 pm –5:00 pm Room 3-442	Thursday 3:00 pm –5:00 pm Room 3-442	Tasks & Project Milestones
1	9/4	No Class	Welcome Course Overview FUNdaMENTALS_Topics 1, 2 & 3	Milestones 1 • Sign up for Hobby Shop http://hobbyshop.mit.edu | hobbyshop-news@mit.edu • A special safety training will be offered at 1:00 pm Friday 9th • Install Solid Works and practice as needed • Being reading FUNdaMENTALS (get ahead!) that YOU think pertains to the lecture material Real engineers prepare for known forthcoming meetings, events…!
2	9/11	**Clinician Presentations**	**Clinician Presentations** Team Formation	Lab - Begin lab assignment. Milestone 2 • Form teams • Begin to research prior art including products, literature and patents
3	9/18	FUNdaMENTALS Topics 4, 5 Announce Teams Overview of Resources Team Dynamics	Patents – Thomas Tachovsky, MIT Tech. Licensing Office Lit Search - Angela Locknar, MIT Libraries	Lab – Design & Model Milestone 3 • Research strategy options, and continue literature and patent review • Create team mission statement • Document literature and prior art search findings (include references)
4	9/25	Keith Durand – Solid Works Good Practices	FUNdaMENTALS Topic 6,7 Danny Braunstein – Prototyping	Ximedica Tour & Presentation leaving at 12 pm on Friday 30th Lab – Build & Test Milestone 4 • Top 3 strategies selected, and described with their FRDPARRC tables completed • One page proposals for bench level experiments
5	10/2	**Teams' Strategy Presentations**	**Teams' Strategy Presentations** ~~**Lab project expo after class (with pizza)**~~	Lab – Evaluate & Write-up Milestone 5 • Conduct bench level experiments to help select strategy • Team Wiki's should be functional
6	10/9	**No Class – Columbus Day**	FUNdaMENTALS Topics 8 Martin Segado – Review of Thermodynamics **Lab project expo after class (with pizza)**	Milestone 6 • Best Strategy Selected with its FRDPARRC table complete • Design and make sketch models for project • Draft of *introduction* section of 2.75 final paper/journal article • Peer evaluation of team members **DMD Abstracts due 15 November**
7	10/16	Clinical Topic – Dr. Perry Rosenthal, Boston Foundation for Sight (2hr)	Clinical Topic- TBA FUNdaMENTALS Topics 9 & 10	Milestone 7 • Develop concepts, run bench level experiments • Report experimental results

				• Top 3 concepts selected, and described with their FRDPARRC tables completed • Create detailed schedule to completion
8	10/23	**Teams' Concept Presentations**	**Teams' Concept Presentations**	<u>Milestone 8</u> • "Best concept" should be selected, and good sketch model done and tested so as to enable "real parts" to be made • Create solid model of "Best Concept" *Special Topic:* Applied Technical Drawing Friday 29th 1:00 – 2:00 pm
9	10/30	Lectures - Case Studies	Kirby Vosburg, PhD – GPS for the Body Vaibhav Patil, MD - Image guidance for neurosurgery	<u>Milestone 9</u> • Most Critical Module (MCM) engineering and bench level experiments • Begin engineering of other modules • Final paper abstract, first paragraph & structure outline • Draft of *background* section of 2.75 final paper/journal article
10	11/6	Dr. Rajiv Gupta, PhD – A Whirlwind tour of Radiology (2hr)	Case Study - TBA Aaron Ross – Ergonomics (1hr)	<u>Milestone 10</u> • MCM complete and demonstrable (ready for the Design Reviews)
11	11/13	**Teams' Design Review**	**Teams' Design Reviews**	<u>Milestone 11</u> • Engineering for other modules started • Begin final manufacturing • Draft of *design/methods* section of 2.75 final paper/journal article; the *methods* draft can be in the form of a testing proposal
12	11/20	**No Class – Staff available as needed** Focus to Finish!	**Holiday** **Happy Thanksgiving**	<u>Milestone 12</u> • Engineering for other modules complete • Integration of modules started • All machining orders in process (later than this and parts won't arrive)
13	11/27	**No Class – Additional team meeting time scheduled with staff** Focus to Finish!		<u>Milestone 13</u> • Prototype complete & ready for testing
14	12/4	**No Class – Additional team meeting time scheduled with staff** Focus to Finish!		<u>Milestone 14</u> • Testing complete and documented, tweaked & ready to present • Presentation dry run • Final paper draft
15	12/11	**13 December** **Final Presentations:** 3:30 – 5 Round 1 (energy) 5-6:30 Dinner / Break 6:30 – 9 Round 2 (medical)	**Work on Deliverables**	<u>Final Deliverables</u> • Journal paper, one pager, PowerPoint slide deck • Peer evaluations • Final Wiki update for archival purposes
16	12/18	**Monday 19 December Sundown – Deliverables**	**Happy Holidays**	<u>Final, Final Deliverables</u> • Relax

		Due		• Overeat