Course Objectives:

- To study the business and social context for developing products.
- To study how product development is accomplished and to actually design a product through the early design stages.
- To focus this knowledge on the Developing World
- To learn team and communications skills

This year we continue our emphasis on Guatemala. We will explore the social context required to develop successful products in general and in Guatemala in particular. In addition there will be a parallel module, with a speakers' series to cover this subject in more detail. Students from Raphael Landivar University, Guatemala City and Art Center in Pasadena will join our teams.

The purpose of this course will be to expose students to the complete spectrum of product development activities from market research to production and after-market support. The course will give insight to products developed using a variety of technologies though technology is not the emphasis of this class. In fact, many useful products can be constructed employing indigenous technologies.

DFX
For all students, good practices will be presented. Design will be presented as a process whose cost, performance, timing, and quality are measurable. Integral with this approach is the adoption of a series of anticipatory design practices which form the core of this course. (These are sometimes referred to as DFX or Design For “X” methodologies.) For example, researched customer desires are taken into account to assure that the product will have a market. This is difficult enough when the customer belongs to a familiar culture. The problem is multiplied when the customer culture differs profoundly from that of the engineer/designer. Another concept covered is product economic return, including the practice of design to a specified cost. This is particularly operative when the customer can only afford a product that provides a fast return. The cost of this product is often very low by developed world standards. An important issue is reliability where we address the question of making products that are robust against use (or misuse) and predictably survive for greater than a specified period. Manufacturability will be covered where the design enables products to be made in the most cost-effective, reproducible fashion in areas with little or no supporting infrastructure. We emphasize the effect on the environment through all phases of the life cycle of a product. This includes manufacture, use and disposal, all considered during the design stage to minimize unhappy surprises. The human interface is another important consideration. In addition to ease of use, this subject also addresses health and safety concerns. Sustainability in a resource-limited world will be addressed by considering the effect of our products on limited natural resources. Ethical discussions, using case approaches, will cover occasions when engineers are faced with choices that conflict with personal values. We will present methodologies for addressing these dilemmas, which arise in the life of every engineer, including, most assuredly, those who build developed world products. We consider also that products are made in a social and political context. It is particularly important for engineers to be aware in the design phase of regulatory issues, IP protection, legal restrictions, misuse and other government and social constraints.

To study these methodologies, there will be a student term project where a student-chosen product concept is developed by a 4-person team. Each of the good practices will be applied to each of the selected projects. The teams will be composed of Caltech students with a Landivar student on each of these teams. Art Center Students will also be assigned to teams.

In accordance with good design process, there will be an opportunity for rapid prototyping to help develop the concept. It is not expected that a complete ready-to-manufacture design will be completed in the limited time available. However, design studies and drawings will be made and perhaps early prototypes could be developed.

The major challenge in this course is to work through the challenges of understanding the market and designing an appropriate product in the very limited time available. Towards that end we offer some alternative approaches.
1. In engineering, the concept of “reuse” is well established. Here we use pre-existing designs as a basis to make necessary improvements without having to redesign from scratch. One approach here is to work on projects which a team in a previous ME/E 105 team has addressed. The new team would make changes as required to bring the product to a higher level of readiness for the market place.

2. Another alternative for a Team which wishes to continue is to register for independent study or work in the summer in Guatemala to implement.

**Mentors**
To assist you, experienced mentors with industry or developing country experience will be assigned to each product team. We are working on assigning Entrepreneurs from Guatemala to each Team.

**Designs Appropriate for the Developing World**
In addition to lectures, we will employ real-life studies, using guest speakers to explore several examples of the application of these principles. As mentioned above, for the subject of products for developing countries, there will be a parallel speaker series which will emphasize the special issues associated with this subject. For these projects, we intend to have a fourth team member from the developing country, working under the guidance of an in-country mentor. Because of their higher organizational complexity we will have these teams in place and the subjects vetted prior to the start of class.

This sequence is being developed in collaboration with the Caltech Chapter of Engineers for Sustainable Development (http://esw.caltech.edu), students from the CASS student exchange program, USAID's Farmer-to-Farmer program at Florida International University, Universidad Francisco Marroquín, and Design that Matters, an MIT-related organization (www.designthatmatters.org)

**Teams**
To increase the team diversity and benefit from their skills, we are inviting students from the Art Center School of Design in Pasadena to join our teams. To participate in this class, you must take these teams very seriously. You are obligated to attend team meetings and bear your share of the burden. Each team member will receive an identical grade for efforts produced by the team. However, there will be some grade differentiation based on contribution to class discussions. We will form these Teams very early in the quarter, beginning the first day of class. At each class homework may be presented by one or more Team.
All Homework will be done by all teams and submitted to the TA and myself on the date due; Your grade ("HW") will be based on these analyses. All other members of the class who are not presenting are required to do the Homework and be prepared to comment. However, only one team will orally present the assignment. You will know in advance when your team will present. The responsibility to present your results will be rotated with each team presenting at least once. This discussion simulates how business profit or non-profit is actually conducted; most business information is transmitted orally through presentation and discussion. Therefore, I will require all students to contribute. I know some students are not comfortable with this and I will make some allowances. However, I do want all to join in and 20% of the grade will be dependent upon this participation.

Please e-mail the instructor and TA all your assignments as well as provide hard copies in the class when the assignment is due.

Expectations
The above only works if the teams work as teams with everybody contributing. No free rides. The Caltech honor code applies here. Everyone in the class, presenting or not, does the homework. Everyone (or almost everyone) attends each class, showing up on time. If you have to unavoidably miss a class, I would like an e-mail or telephone message in advance informing me of the fact. There will be periodic team assessments to assure that the teams are functioning well. If there are irresolvable issues, teams can be broken up and the members re-assigned. This should be a rare occurrence.

This is the kind of learning where looking up lectures on the web or just doing the assigned readings will not suffice. The student needs to follow the arguments made and participate in arriving at an acceptable conclusion. The journey in getting there is part of the learning experience. Mathematically, the formula is as follows:

Learning = f(team effectiveness + team preparation + rest-of-class preparation) X (class attendance)

Guest Speakers
We will also hear some guest speakers who will discuss how these principles apply in their industries. There will be a parallel speaker Series which will present additional materials related to building products for a sustainable world. Each student will be required to
term product design assignment

1. Choose a team. Optimum is 3 people. If you don’t know other people in the class, don’t despair, we can assist in team formation. Teams will be formed before classes start or at maximum during the first week.

2. Choose a product to design

   Examples:
   - Product ideas presented to you the first day of class
   - A solar-operated fan for a developing country
   - Projects designed to satisfy basic needs (clean water, simple transportation, energy, etc.) in the developing world
   - A security project e.g. an electronic lock which is controllable remotely
   - A design based on business plan of E102
   - A Research Project you are involved in which has productization potential
   - Other ideas arising from brainstorming.

   We can assist also in this process but the best ideas, the ones you feel most passionate about, are often ideas that you invent yourself.

2. Use tools described in Class including at least 8 of the following tools (should some of these be required?)

   Design for appropriateness in the chosen market
   Design for Sustainability
   Design for the Environment
   ROI and Financial Considerations
   Market Research
   Design for Manufacturability and Assembly
   Systems Architecture Considerations
   Product Platforms
   Risk Mitigation Analysis
   Test and Testability
Design for Cost
Design for Maintainability
Human Interface- Ergonomic Design
Quality Design
Invent your own based upon principles taught in class

Design a “virtual product using these tools”. It is advantageous to build an engineering model which demonstrates functionality. The ME shop is available for your assistance. Please contact John Van Deusen. (jvand@caltech.edu, X4120). Another possibility is to use rapid prototyping to create a mock up of your product. Realistically, given time constraints, your results might be limited to “paper analysis”.

There will be a paper and presentation at the Midterm and Final.

**Timetable**

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
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<tbody>
<tr>
<td>Teams formed</td>
<td>September 30</td>
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<tr>
<td>Lecture on Teams</td>
<td>October 4</td>
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<tr>
<td>Term project Proposal due</td>
<td>October 4</td>
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<td>Term projects Accepted</td>
<td>October 11</td>
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<tr>
<td>First team meeting</td>
<td>October 21-28</td>
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<td>Mid-course Report due</td>
<td>November 3</td>
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<td>Team Report due</td>
<td>November 17</td>
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<tr>
<td>Final Report due</td>
<td>December 2</td>
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<tr>
<td>Presentation due</td>
<td>December 2</td>
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The Final report should be a maximum of 20 pages double-spaced. It should include the Design plus the thinking that went into creating this Design. We will have a poster session after the Final Presentations. Interested members of the community will be invited to hear your talk and to discuss your results.
The Midterm Presentation should take about 20 minutes (~ 10 PowerPoint slides). The Final presentation should take also about 30 minutes or 15 Slides. An outline of the contents will be discussed in the Class.

The TA and I are available continuously for counseling on this assignment. Please feel free to call on us.

**Grades**
20% HW, 20% Midterm Assignment 30% Final Term Assignment, 20% class participation. In addition, each team will have 10 points to allocate amongst team members. (Each Team will allocate 100 points by Team consensus to its members depending on contribution. For example if the agreed allocation is 50 points for member A, 30 points for member B and 20 points for member C, then A will get $(50/33)(10)$, B will get $(30/33)(10)$ and C will get $(20/33)10$. Thus a team member can get more or less than the allocated 10 points depending on their contribution.

Your HW grade will be based on your written answers submitted to me. In my grading, I look for understanding of the material and originality. Your Midterm and Final assignments grades are also based on these criteria. We will not grade on your presentation style; however I will give you feedback on how well I thought you organized and presented the material.

**Auditing**
Although auditors are welcome, it is clear from the above that the amount of learning accomplished is directly proportional to the effort expended. Naturally, this is true of anything you would want to learn. In this course, merely perusing notes or lecture slides after the fact is not as useful as you would think unless have a position of knowledge of what the discussion is all about. Auditors might consider forming teams with other auditors.

**Course Text**
On Reserve: “Contemporary Engineering Economics” Chan S. Park

**Required Readings:**
1. UN: The Millennium Development Goals Report 2005
5. Sky Marsen. “Organizational Communication”
8. Ford advertisement from New Yorker
9. Carly Fiorina’s 2004 commencement speech

Additional reading and references can be found on the course webpage.

Course Follow-on

For those students interested in continuing with their product through to the next stage, your work can be pursued in the next Class in the sequence: E 102 Entrepreneurial Development where we can pursue a business plan to commercialize your product. Other flexible, independent study alternatives will also be possible for those who desire to continue product design through to manufacturing models and beyond.

**The 2006 Schedule**

<table>
<thead>
<tr>
<th>Date</th>
<th>Subject</th>
<th>in Class</th>
<th>HW Assignment</th>
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<tbody>
<tr>
<td>9/10-9/11</td>
<td>Meet with Landivar Faculty and Students</td>
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<tr>
<td>Date</td>
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<tr>
<td>9/12</td>
<td></td>
<td>Landivar introduction</td>
<td>Landivar introduction: Class expectations and choice of product candidates</td>
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<tr>
<td>09/26</td>
<td>Tue</td>
<td>Introduction and Organizational</td>
<td>Caltech and Art Center Course objectives, expectations, introductions. Discuss candidate product topics. Begin Team formation in class. Work on forming Teams</td>
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<td>Date</td>
<td>Topic</td>
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<td>10/05 Thur</td>
<td>Marketing lecture 2 with Developing World focus</td>
<td>Present Topic, Team, Mission Statement, Teaming agreements, Lecture: How do we know what the market wants or needs? What about products in developing countries? What is the situation in the developing world? What do we mean by design for developing countries? What is our goal (profit, development) What are possible business models</td>
<td>Tuesday 10/11: Market Research Plan Read Ulrich and Eppinger Chapter 5 on Product Specifications</td>
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<tr>
<td>Date</td>
<td>Time</td>
<td>Subject</td>
<td>Notes</td>
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| 10/12      | Thur/14 | Sustainability                  | Stakeholder Analysis. Sustainable Engineering Design for Products in the Developed and Developing World.  
Due Tuesday 10/17:  
Read U&E Chapter 9 on Product Architectures |
| 10/17      | Tue    | Begin Product Architecture      | Team presentations: Marketing results to date: who is the customer, what is the size of the market, what does the customer want?  
How to architect a system. Is there a structured way of thinking about partition of function?  
Due Tuesday 10/23: Show some candidate architectures for your product. Which did you choose and why? |
| 10/29      | Thur   | Finish product architecture     | Team Presentations on product specifications  
Lecture on Human Factors, aesthetics, maintainability, testability  
Each team schedules meeting with Sky on Oct 21-28 on Team results to date. Bring a draft or outline of your final “Team Report” to this meeting  
Due Tuesday 10/24:  
Read Chapter 10 of Ulrich and Eppinger on Industrial Design |
| 10/24      | Tue    | Industrial Design               | Team Presentations on candidate architectures  
Lecture: From architecture to detailed design. Industrial Design  
Due Thursday 10/26:  
What are your strategies for Human Factors and aesthetics? |
| 10/26      | Thur   | Reliability, FMEA               | 10 minute presentation of your results to date  
Lecture: Tools to design products, robust against unintended uses as well as against flaws that can cause early failure.  
Due Tuesday 10/31:  
1. Submit detailed design on key component of system  
2. Strategies to make your product reliable and maintainable in the developing world, FMEA |
| 10/31      |       | Design for the                  | HW Presentation on Failure Analysis |
| 10/17      | Tue    |                                    |  
Due Tuesday 10/17:  
Read U&E Chapter 9 on Product Architectures  
Due Tuesday 10/23: Show some candidate architectures for your product. Which did you choose and why?  
Due Tuesday 10/24:  
Read Chapter 10 of Ulrich and Eppinger on Industrial Design  
Due Thursday 10/26:  
What are your strategies for Human Factors and aesthetics?  
Due Tuesday 10/31:  
1. Submit detailed design on key component of system  
2. Strategies to make your product reliable and maintainable in the developing world, FMEA |
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<tr>
<th>Date</th>
<th>Activity</th>
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<th>Due Date</th>
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<tbody>
<tr>
<td>11/02 Tue</td>
<td>Environment Lecture: Design for the Environment in a Developed Country. Sustainability</td>
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<td>Tuesday 11/07: Read Chapter 11 of U&amp;E Design for Manufacturing</td>
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<tr>
<td>11/02 Tue Ken Away</td>
<td>Design for Manufacturing Factory operations DF Assembly, Building device model for demonstration How do factories actually work? How can you avoid designing the unbuildable? Outsourcing challenges and limitations. Manufacturing/Assembly challenges in developing countries.</td>
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<td>Tuesday 11/14: Read HBS Case and Vodacom case Answer question: What in your opinion was Maddy’s mistake? Do you agree with her analysis? What would you do differently? Why did Vodacom’s model work when Maddy’s didn’t?</td>
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<td>11/09 Thur</td>
<td>Financial Considerations Presentation on Manufacturability Strategy Lecture: NPV, Pro forma, Payback time, design to Cost, Bill of Materials. Applications to developed and developing worlds</td>
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<td>Tuesday 11/21: C. K. Prahalad and Allen Hammond. “Serving the World’s Poor, Profitably” Do you have ethical concerns about this paper?</td>
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<td>11/14 Tue</td>
<td>Case History Telecom in Tanzania Monique Maddy (alternative: Guatemalan Case)</td>
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<td>11/16 Thur</td>
<td>Guest Lecturer Students present 5 minutes on Team Learnings. Two pages Team Report due. Teams present progress to date.</td>
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<tr>
<td>11/21</td>
<td>Ethical Consideration</td>
<td>Other Constraints in Developing products. The role of Government and Law. Ethical Considerations</td>
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<tr>
<td>11/23</td>
<td>Thanksgiving holiday</td>
<td>No Class</td>
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<tr>
<td>11/28</td>
<td>Summary lecture</td>
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<tr>
<td>12/01</td>
<td>Final</td>
<td>Final Presentations by Team and Submission of Final Report Due</td>
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<td>Demonstration of Rapid Prototype or Engineering Model, if available</td>
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