ES402 System Engineering Design

Credits: 2-4-4
Course Description: This course acts as a capstone laboratory in Systems Engineering. It provides students with the opportunity to use fundamental knowledge acquired in preceding courses to be used in the instantiation a final design project (from concept to prototype to final documentation). The course includes an introduction to the macro-techniques of engineering design including performance, reliability, management control, redundancy, man-machine systems and testing techniques. Design, construction, test and evaluation of an approved project is accomplished in the lab.

Course Outcomes
Students will:

(1) have an ability to apply knowledge of mathematics, science, and engineering in identifying, formulating, and solving engineering problems
(2) have an ability to apply the modern engineering techniques, skills, and tools necessary for engineering practice. Specifically, they will have an ability to apply modern engineering techniques, skills, and tools in designing and conducting experiments and analyzing and interpreting data
(3) have an ability to design a system, component, or process to meet desired needs
(4) have an ability to function and communicate effectively in multi-disciplinary teams
(5) have knowledge of contemporary issues, an understanding of professional and ethical responsibilities, and understand the impact of engineering solutions in a global and societal context
(6) recognize the need for, and have an ability to engage in life-long learning
ES402 COURSE POLICY

From:  Associate Professor Matthew Feemster
To:    ES402 advisees

This course acts as a capstone to your undergraduate education in Systems Engineering. It provides you with the opportunity to use most of the fundamental knowledge you have acquired in the preceding courses, culminating in a design project, which you are carrying out from concept through final documentation.

Expectations
• At a minimum, we will all meet once per week, all group members will attend. Missing the meeting is equivalent to missing a lecture period for a traditional course.
• Each member of the group will put in about 8 hours/week on the project for a 4 credit course.
• When a technical stumbling block arises you won't simply wait until the next weekly meeting time to discuss it. You will arrange a one on one EI meeting or send me an e-mail for advice.
• When we meet, you will be completely set up prior to my arrival. That means computer booted, logged on, code opened, parts connected, etc.
• You will show me your draft report/presentation/poster at least 1 week before its due, so that you have time to incorporate my comments.
• At the end of the course you will schedule a day to transfer your knowledge to me. This would include burning all code and data to a CD; supplying me with wiring diagrams; and providing me with a 1 page instruction sheet on how to run the demo.

Weekly meetings
At least 4 business hours prior to our weekly meeting, send me an e-mail containing:
• A bulleted list of accomplishments for the last week.
• Biggest current challenge / technical question you want to discuss.
• Hours logged.

Demonstrations
• During the 2nd and 8th week of class, we will decide what will be your 6 and 12 week milestones will be. Aim high, but be realistic.
• Demonstration day will be our last meeting before the day grades are due.
• Demonstrations should be configured as “one click start” which means they are all ready to go at the beginning of the meeting.

Grading
15%  6 week demonstration.
15%  12 week demonstration.
20%  Attendance of weekly meetings.
20%  My perception of your effort.
15%  Final project quality.
15%  Final presentation and report.
This document summarizes the application and assessment of System Engineering Program Outcomes in ES402, *System Engineering Design*, during the 2012 spring semester.

**B. Summary of Course**

This course is a capstone to the Systems Engineering major. It provides the students with an opportunity to use the fundamental knowledge they have gained in preceding systems engineering courses to complete a design project of their choice. In the laboratory portion of this design experience they practice the steps taken by professional engineers as they see a design to completion: from initial conceptualization and design (ES403), through measurements and experiments, iterative construction, testing, and evaluation, to formal presentation, and final documentation (formal written report). Since the design project is a major objective of this course, successful completion of the project is a requirement for successful completion of the course. Because the project is of no value to others if information about it is not passed on, a satisfactory formal report is crucial to the successful completion of the project.

**C. Outcomes Addressed in Course**

Outcomes 1, 3, 4, and 5 were addressed during this cycle (Spring 2012). Enclosure #1 lists methods that are used to assess the students’ mastery of a particular outcome.

**D. Summary of Previous Recommendations**

The following items were suggested for improving ES402.

**Recommendation**: Require a draft of the final report to be provided to the advisor at the student’s presentation. This will ensure that at least one revision cycle is done prior to final submission. (See the recommendations for 2013.)

**Recommendation**: Schedule presentations in one hour blocks. This will provide adequate time to discuss projects without being rushing off to a subsequent presentation. This may require a greater length of time to cover a large senior class. I also suggest the presentation time be selected by the ES402 coordinator to ensure spacing; however, this may require excusal from select classes. I am not sure how difficult that this will be. (See the recommendations for 2013. This idea could be considered in the single-day, parallel session format.)

**Recommendation**: Include a more pointed question (probably in the exit Survey) to evaluate Outcome #1. For example, “Did you utilize a formal approach in the design/simulation/or execution of your project?” “Did you list any assumptions under which analysis was performed?” (This idea could be included in the exit survey and the grading sheet.)

**E. Changes in the Course**

The presentations were organized by topic as in a conference. Surprisingly, there were only a few scheduling conflicts and the presentations flowed naturally. Also, reports were standardized using a common title page and
spiral binding. Finally, each group was required to create an electronic Power Point poster that can be used in future recruiting activities.

F. Assessment Methods Implemented

The final project reports were the venue for formal assessment in ES402 because technical difficulties prevented the Exit Survey from being implemented. The final project reports were evaluated using the departmental scoring sheet in Enclosure #2. The departmental scoring sheet concentrated on particular areas related to Outcome 3 (Engineering Design). In most cases, we were looking at specific performance criteria at a particular place in the paper. Outcome 4 (Communications and Teams) and Outcome 6 (Life-long learning) could not be evaluated via specific questions on the Exit Survey.

G. Assessment Results

All scores are based on a 0 to 4 scale. Outcome #1 was assessed utilizing material from the final project report grading sheet.

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>(f) Discuss the mathematical and engineering assumptions used in formulating and solving engineering problems and evaluate the feasibility of the solution and/or determine feasible solutions from infeasible ones.</td>
<td>Design narrative (from report)</td>
<td>3.69</td>
<td>3.2</td>
<td>3.5</td>
</tr>
<tr>
<td>(g) Partition complex problems into manageable parts and develop strategies for dealing with open-ended problems.</td>
<td>Function list</td>
<td>3.17</td>
<td>2.8</td>
<td>2.9</td>
</tr>
</tbody>
</table>

Table 1: Outcome #1 Assessment Results

Remark: The scores presented in Table 2 show that the students’ performance has remained consistent over the past three years. It should be noted that the scores for the Function List reflect 0 scores when the list is not included.

Table 2 summarizes the scores from for Outcome #3 criteria areas for Spring 2012. As mentioned above, the scores were obtained from the final report grading sheet. A summary of the scores for final reports is included in Enclosure #2. Please refer to the Outcome #3 assessment summary for trends over previous years.

Remark: The scores presented in Table 2 were based from the students’ advisors grading of their final project report (see Enclosure #3). It has been witnessed in the past the design and construction of a great project throughout the semester only to be followed by a disappointing presentation and/or report.
### Table 2: Outcome #3 Assessment Results

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<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>(a) Produce a clear and unambiguous statement from various inputs.</td>
<td>3.61</td>
<td>3.75</td>
<td>3.2</td>
<td>3.6</td>
</tr>
<tr>
<td>(b) Determine design objectives and functional requirements based on need.</td>
<td>3.5</td>
<td>3.11</td>
<td>3.2</td>
<td>3.4</td>
</tr>
<tr>
<td>(c) Develop design strategy and establish a timetable and milestones by which progress can be evaluated</td>
<td>2.61</td>
<td>1.81</td>
<td>2.4</td>
<td>2.5</td>
</tr>
<tr>
<td>(d) Employ models, representations, such as functional block diagrams, and simulations of the physical world to provide information for design process.</td>
<td>3.24</td>
<td>3.17</td>
<td>3.3</td>
<td>2.9</td>
</tr>
<tr>
<td>(f) Critique the finished prototype and suggest improvements.</td>
<td>3.33</td>
<td>3.83</td>
<td>3.2</td>
<td>3.6</td>
</tr>
</tbody>
</table>

**Remark:** The scores for 3 (c) (Gantt chart item on ES402 report scoring sheet) and 3 (d) (functional block diagram item on ES402 report scoring sheet) over the past four years include 0 scores when these items are omitted. As a result, these scores represent accurately that the students’ performance has remained consistent. However, the level of the students’ performance is higher than the scores for 3 (c) and 3(d) indicate.

Table 3 summarizes the assessment results for select Outcome #4 topics as evaluated from the ES402 final report scoring sheet. The four years of data show consistently good performance.

### Table 3: Outcome #4 Assessment Results (from project report)

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>(e) Effectively communicate information, concepts, and ideas in writing</td>
<td>3.42</td>
<td>3.50</td>
<td>3.4</td>
<td>3.4</td>
</tr>
<tr>
<td>(g) Effectively communicate information, concepts, and ideas, graphically</td>
<td>3.89</td>
<td>3.47</td>
<td>3.6</td>
<td>3.7</td>
</tr>
</tbody>
</table>

### H. Recommendations for 2013

Here are the recommendations for the course:

1.) The Division of E & W piloted a division-level project show this year and has discussed a division-wide Capstone Day. **It is recommended** that the department have a Systems Engineering Capstone Day on the last day of classes. All presentations would occur on this day in three or four parallel sessions. The benefits of a Systems Engineering Capstone Day would be

- ES402 students would have until the last day of class to put the final touches on their project.
- All Systems classes would be cancelled so Systems Engineering majors and Systems Engineering faculty would be free to attend presentations.
- We would be more likely to have guest reviewers attend for one day.

2) If the project presentations are scheduled for the last day of classes, **it is recommended** that the final draft of the project report be submitted to the project advisor at least one week prior to the last day of classes. The students would have time to revise their reports based on their advisors comments and submit them at the presentations. This change would ensure that the report reflects the construction, testing, and evaluation performed in ES402 and that essential elements (e.g. Gantt chart, functional block diagram) are not omitted.
3) While advisors have given high scores for the design critique, it would be helpful to provide additional structure in the ES402 schedule to increase the students’ time for testing and evaluation. Currently, advisors set milestones for their project groups at the 6 and 12 week points. **It is recommended** that students be required to have a working prototype of at least one major subsystem before Spring Break (typically, the 9th week).

4) Outcome #1 (From 2010): Include a more pointed question (probably in the exit Survey) to evaluate Outcome #1. For example, “Did you utilize a formal approach in the design/simulation/or execution of your project?” “Did you list any assumptions under which analysis was performed?”

Sincerely,

Rich O’Brien
ES402 Course Coordinator
## ES402 Systems Engineering Design

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Elements Contributing to Outcome</th>
<th>Blooms Level&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Assessment Methods</th>
</tr>
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<tbody>
<tr>
<td>(1) have an ability to apply knowledge of mathematics, science, and engineering in identifying, formulating, and solving engineering problems [a,e]</td>
<td>Senior capstone project construction and evaluation.</td>
<td>Evaluation</td>
<td>Design reports and student responses from exit survey</td>
</tr>
<tr>
<td>(2) have an ability to apply the modern engineering techniques, skills, and tools necessary for engineering practice. Specifically, they will have an ability to apply modern engineering techniques, skills, and tools in designing and conducting experiments and analyzing and interpreting data [b,k]</td>
<td>Senior capstone project construction and evaluation.</td>
<td>Evaluation</td>
<td>Design reports and student responses from exit survey</td>
</tr>
<tr>
<td>(3) have an ability to design a system, component, or process to meet desired needs [c]</td>
<td>Senior capstone project construction and evaluation.</td>
<td>Evaluation</td>
<td>Design reports and student responses from exit survey</td>
</tr>
<tr>
<td>(4) have an ability to function and communicate effectively in multi-disciplinary teams [d,g]</td>
<td>Senior capstone project construction and evaluation</td>
<td>Evaluation</td>
<td>Design reports and student responses from exit survey</td>
</tr>
<tr>
<td>(5) have knowledge of contemporary issues, an understanding of professional and ethical responsibilities, and understand the impact of engineering solutions in a global and societal context [f,h,j]</td>
<td></td>
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<tr>
<td>(6) recognize the need for, and have an ability to engage in life-long learning [i]</td>
<td>Senior capstone project construction and evaluation</td>
<td>Comprehension</td>
<td>Design reports and student responses from exit survey</td>
</tr>
</tbody>
</table>

<sup>1</sup> For a description of each Blooms level, see U:\ABET\Resources\attributes.pdf.
<table>
<thead>
<tr>
<th>Report Content</th>
<th>F</th>
<th>D</th>
<th>C</th>
<th>B</th>
<th>A</th>
<th>Score</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title page</td>
<td>None</td>
<td>Just group name</td>
<td>Group name and advisor name</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Abstract</td>
<td>Irrelevant or misleading</td>
<td>Partial abstract covering only part of the paper</td>
<td>Clear synopsis of the paper</td>
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<td>Background information</td>
<td>No background or related work</td>
<td>Some background work, but some crucial areas missing</td>
<td>Good coverage of previous work/projects</td>
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<tr>
<td>Problem statement</td>
<td>Unclear problem statement</td>
<td>Vague statement of project direction</td>
<td>Clear and complete statement of problem</td>
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<tr>
<td>List of deliverables</td>
<td>No deliverables listed</td>
<td>Vaguely defined set of deliverables</td>
<td>Fully articulated set of deliverables</td>
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<tr>
<td>Constraints</td>
<td>None</td>
<td>A few obvious constraints</td>
<td>A full set of constraints and assumptions</td>
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<td></td>
<td></td>
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<tr>
<td>Objectives</td>
<td>None</td>
<td>Poor granularity</td>
<td>Full set of objectives</td>
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<td></td>
<td></td>
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<tr>
<td>Final design presentation</td>
<td>No presentation of final system</td>
<td>Unclear description or lacking appropriate detail</td>
<td>Clear and detailed presentation of final design</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Design narrative</td>
<td>No narrative of how final design was arrived at</td>
<td>Some discussion but some aspects of final design not covered</td>
<td>Clear discussion of how all aspects of final design was arrived at</td>
<td>3</td>
<td></td>
<td></td>
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<tr>
<td>Functional block diagram</td>
<td>None</td>
<td>FBD is poorly annotated (some interface details)</td>
<td>Full FBD with details as appropriate</td>
<td>3</td>
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<tr>
<td>Gantt chart</td>
<td>None</td>
<td>Gantt chart has poor details, not well defined, or has not been updated</td>
<td>Gantt chart is comprehensive and reflects timeline of project.</td>
<td>3</td>
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<tr>
<td>Function list</td>
<td>None</td>
<td>Poorly defined or incomplete</td>
<td>Full function list representing all aspects of the project</td>
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<tr>
<td>List of performance metrics/measures</td>
<td>None</td>
<td>Metrics only (for objectives) or measures only (for functions)</td>
<td>Both metrics and measures (all appropriate)</td>
<td>3</td>
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<tr>
<td>Demonstration plan</td>
<td>No demonstration plan</td>
<td>Plan to demonstrate the satisfaction of some objectives and deliverables, or missing some measures/metrics</td>
<td>Plan to demonstrate the satisfaction of all objectives and deliverables with measures/metrics</td>
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<td>Evaluation of performance metrics/measures</td>
<td>No evaluation of project against proposed performance metrics/measures.</td>
<td>The project was evaluated against select performance metrics/measures (relevant ones omitted).</td>
<td>The project was evaluated against all appropriate performance metrics/measures.</td>
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<tr>
<td>Design critique</td>
<td>No critique of design project</td>
<td>Constructive critique but no guidance on future improvements</td>
<td>Constructive critique/comments for improvement of design</td>
<td>2</td>
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<tr>
<td>Final equipment list</td>
<td>None</td>
<td>Partial list</td>
<td>Complete list</td>
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<tr>
<td>Budget/cost</td>
<td>No budget or cost provided for project</td>
<td>Incomplete cost of project</td>
<td>Complete budget/cost of project</td>
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<tr>
<td>Utilized a variety of information sources</td>
<td>References not cited in body of paper, or no bibliography</td>
<td>Only a few references cited in body of paper, good bibliography</td>
<td>Numerous and varied references cited in body of paper, good bibliography</td>
<td>1</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Report Content</td>
<td>F</td>
<td>D</td>
<td>C</td>
<td>B</td>
<td>A</td>
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<tr>
<td>Communicate information, concepts in writing</td>
<td>Poor communication, poor writing</td>
<td>Adequate communication, adequate writing</td>
<td>Ideas, concepts communicated in clearly written paper</td>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td>Communicate information, concepts, ideas graphically, graphs, charts, diagrams, technical schematics, sketches</td>
<td>Unclear graphics, charts, diagrams, etc. (causes reader confusion)</td>
<td>Irrelevant or unclear graphics, charts, diagrams, etc.</td>
<td>Relevant and clearly useful information (helps to support text)</td>
<td>2</td>
<td></td>
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<tr>
<td>Meet with adviser</td>
<td>Never</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Used discovery/reverse engineering to help design project</td>
<td>Did not use discovery or revere engineering within design project</td>
<td>Found a similar system (mechanical, electrical, code) but did not break down system to discover function (or how it worked)</td>
<td>Found a similar system (mechanical, electrical, code), discovered how it functioned, and modified for their project</td>
<td>0</td>
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</tbody>
</table>

Do not calculate scores.

RECOMMENDED REPORT LETTER GRADE

Signature: __________________________________________________________________________
## ES402 Final Report Scores

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</tr>
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<tr>
<td>Abstract</td>
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<td>Background information</td>
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<td>Problem statement</td>
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<td>1.2</td>
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<tr>
<td>Objectives</td>
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<tr>
<td>Final design presentation</td>
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<td>Design narrative</td>
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<td>0.7</td>
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<tr>
<td>Functional block diagram</td>
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<td>1.5</td>
</tr>
<tr>
<td>Gantt chart</td>
<td>2.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Function list</td>
<td>2.9</td>
<td>1.2</td>
</tr>
<tr>
<td>List of performance metrics/measures</td>
<td>3.1</td>
<td>1.3</td>
</tr>
<tr>
<td>Demonstration plan</td>
<td>3.2</td>
<td>1</td>
</tr>
<tr>
<td>Evaluation of performance metrics/measures</td>
<td>3.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Design critique</td>
<td>3.6</td>
<td>0.8</td>
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<td>Final equipment list</td>
<td>3.5</td>
<td>1.1</td>
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<tr>
<td>Budget/cost</td>
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<tr>
<td>Utilized a variety of information sources</td>
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<td>1.5</td>
</tr>
<tr>
<td>Communicate information, concepts in writing</td>
<td>3.4</td>
<td>0.9</td>
</tr>
<tr>
<td>Communicate information, concepts, ideas graphically, graphs, charts, diagrams, technical schematics, sketches</td>
<td>3.7</td>
<td>0.5</td>
</tr>
<tr>
<td>Meet with adviser</td>
<td>3.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Used discovery/reverse engineering to help design project</td>
<td>3.2</td>
<td>1.4</td>
</tr>
</tbody>
</table>