Full Paper: A Systems Engineering Approach to Conceptual Design in a 1st-Year Engineering Program

1st-year engineering students engage in three projects over the course of the fall and spring semesters. In the fall semester students build, test, and present at an exposition an Arduino-based game. While students are provided the design for the game, they are strongly encouraged to make creative modifications. Following this, students complete a reverse engineering activity on a simple household appliance or medical device. The result is a CAD model of the device and a detailed report, typically of about 40 – 50 pages. Students work in teams of three or four on both projects.

In the spring semester work consists of a semester long conceptual design project. Students are given a one or two paragraph description of an item to be designed. The items are either devices to aid an individual with a disability or improvements in home kitchens to reduce the use of energy or its waste. Examples from this semester include: An energy efficient bread toaster; a blood pressure monitor for persons with the use of only one arm; a device to harvest kitchen waste energy; a toaster oven for blind persons; and more.

Students work in groups of six on these spring projects. At the beginning students must bring more clarity to the one or two paragraph description. They must better understand what they are being asked to design. They do this by a research paper. Then they write requirements, a necessary step in any design process. A Program Manager (PM) is assigned to each project. This is either a graduate teaching assistant or one of the courses instructors. The PM gives the students four or five higher level requirements. The students must write the remaining requirements that follow from these higher level requirements. To do this they must further research the subject area, submit their requirements to the PM, and get them approved. This process takes several weeks. The engineering school librarian provides instructions on doing a literature search. The students write a second research paper on what they have found. There is a laboratory exercise and several lectures in which the students learn how to write requirements with the correct structure and intent.

Once all the requirements are approved, students start the next phase of the design process by brainstorming possible designs that meet the requirements. They are given instruction in the Pahl and Beitz method to choose the design alternative that best meets the requirements. They must verify through mathematical analysis, simulation, or logical argument that their design meets each requirement. The result is an 80 – 100 page report that fully captures all their work, their alternative designs, their selection process, and verifications. Students also give a presentation in their class summarizing their work.

Finally, from the approximately six or seven student teams on each project the PM for each project selects what is believed to be the best design. Certificates are given to each student on the best design team at an end-of-semester gathering of the entire 1st-year engineering class of about 300 students.