TEACHING ENVIRONMENTAL SYSTEMS ENGINEERING

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ABSTRACT

The Systems Engineering Department at the U. S. Naval Academy has introduced a track in environmental systems engineering. The track consists of a sequence of two courses. The first course is taught within the Systems Engineering Department. This course addresses areas where systems engineers impact environmental issues. The course concentrates on environmental hardware, sensors, data handling, and modeling. For the second course in the track, students choose from two traditional environmental courses in the Ocean Engineering Department at the Naval Academy. One course centers on marine pollution: its causes, effects and remediation. The other course centers on ocean resources: their identification, recovery and utilization. This paper presents an overview of the Environmental Systems Engineering track and focuses on the Systems Engineering Department's environmental course. It discusses the course philosophy, content, and labs.

1. INTRODUCTION

As the country's environmental concerns expand, engineers in all disciplines have to be more aware of environmental issues. Environmental engineering is no longer just the domain of civil and chemical engineers. Environmental issues span the entire engineering profession. To address the growing influence of environmental issues in engineering, the Systems Engineering Department at the United States Naval Academy has introduced a track in environmental systems engineering.

In the Systems Engineering curriculum at the United States Naval Academy, students study the interaction between mechanical, electrical, and computer systems. The curriculum focuses mainly on linear systems theory, feedback control, and mechatronics. It is a four year, undergraduate, ABET accredited, engineering program. Throughout the curriculum students learn how to model, simulate, and design various types of systems.

So how does environmental engineering fit in with systems engineering? This is the most common question asked by our students. To illustrate, consider an agency interested in monitoring the water quality of a river. The agency would compile a team of scientist, mathematicians, and engineers for the task. The scientists and mathematicians would be primarily concerned with what kind of data is collected from the study. The engineers, on the

other hand, would be concerned with the details of gathering the data. The engineers would be responsible for the design and implementation of the data collection system. This falls right in the realm of the systems engineer. For an other example, consider the automatic regulation of the biomass in a waste water treatment plant[1]. The systems engineer would be concerned with orchestrating the sensors, control methodologies, and the flow values to achieve a desired biomass.

The environmental track is designed to have the students apply their systems engineering tools to environmental engineering problems. The track consists of a sequence of two courses. The first course is taught within the Systems Engineering Department. The course is intended to be a survey course exposing students to the environmental concerns in the world today while showing them how they can apply their system engineering skills towards solving some of the problems they encounter. This course addresses areas where systems engineers impact environmental issues. The course concentrates on environmental hardware, sensors, data handling, and modeling. For the second course of the track, students choose from two traditional environmental courses in the Ocean Engineering Department at the Naval Academy. One course centers on marine pollution: its causes, effects and remediation. The other course centers on ocean resources: their identification, recovery and utilization.

In the following sections we discuss the logistics of teaching an environmental engineering course in a systems engineering department, the course content, and assignments. The last section highlights the two traditional environmental courses that follow in the track.

2. COURSE CONTENT
The content of the environmental systems engineering course by topics is:

1. Environmental sensors, data gathering
2. Energy conversion/storage
3. Solar energy systems
4. Student presentation - alternate energy sources
5. Environmental models, mass and energy transport
6. Thermal systems
7. Environmental data, signal processing
8. Student presentation - man's intervention, unintended consequences

It should be obvious from the course content that several areas of expertise are required to address these diverse topics.

3. ASSIGNMENTS/LABORATORIES
The easiest way to discuss the kinds of assignments and laboratories in the course is to address each of the course content topics given above.

1. Environmental sensors, data gathering:

After a cursory review of operational amplifiers[2] each team (two students)

receives a different environmental sensor selected by the faculty for the course. The team receives a data sheet for their sensor and is expected to design a signal conditioning board. The student's sensor and accompanying circuitry is then mounted in an environmental collection box along with other sensor circuits that their classmates design. We eventually place this box outside to gather several weeks of data. The box is cabled into the building to a computer. The data is stored in MATLAB[3] for further analysis. Standard laboratory reports on all student work is required.

2. & 3. Energy conversion/storage and solar:

As part of our discussion about energy conversion and storage, students learn about batteries, capacitors and flywheels. In lab students monitor the discharge characteristics of common batteries and construct their own primitive battery from commonly available materials.

Homework problems culminating in the design of a full solar system for camping are assigned to the students. Also, a model solar powered water pumping station and energy storage system is constructed by each team. The solar tracker portion of this system is of very high interest to our students.

5. & 6. Environmental models, mass and energy transport and thermal systems:

A channel with cold water (a "river") running in it is instrumented with temperature sensors. A hot water (a "power plant") source dumps into the channel and the sensors measure the resulting temperature distribution. Models and simulations for this environmental phenomenon are validated with real data collected from the channel.

A box with a hair dryer blowing into it gives us a nice control system to regulate temperature. A computer does the control (C-Program) and a temperature sensor provides the data.

7. Environmental data, signal processing:

Some very elementary signal processing algorithms are presented[4]. Environmental data is first simulated to get all the methods working. Then the actual data from the environmental box is addressed.

The Environmental Systems course has several homework assignments and laboratory reports to support each of the activities listed above. We also have a one hour test and a three hour final examination. We obtain further input from the students when they give presentations to the class on selected topics.

4. COURSE LOGISTICS

One reason for offering an environmental systems course in our program was to tap the great diversity of interest and expertise amongst the faculty in Systems Engineering. As an example of this diversity, the first time we team-taught the course the primary instructors were a chemical engineer, an electrical engineer, a mechanical engineer, and a computer scientist. The team-teaching format was very successful for the first two times the course was offered. It is now our departmental decision to leave the team-teaching format in this course. Obviously, it complicates our scheduling to do so, but the team-teaching format adds vitality and broadens the scope of the material to be addressed.

Several labs are necessary on a part-time basis to support the Environmental Systems course including an electronics classroom, elementary circuits laboratory and access to water for some of our river modeling experiments.

In summary this course has required a significant commitment by our department to insure its success. Based upon our students' enthusiasm for the course/laboratory, we feel the course has been worth the sacrifices.

5. THE ENVIRONMENTAL SYSTEMS ENGINEERING TRACK

A track in our Systems Engineering major is comprised of a two-course, sequential offering. The first course in the track, Environmental Systems Engineering is the topic of this paper. The second course in the track may be either one of two courses taught by our Ocean Engineering Department. These two courses are described below:

EN411: Ocean Environmental Engineering I (2-2-3). Introduction to the basic principles and current issues in environmental engineering as applied to the ocean environment. Principal focus is on <u>Marine Pollution: Its Causes, Effects and Remediation</u>. Topical coverage includes chemical and biological considerations in water quality; wastewater treatment and discharge; diffusion and dispersion in estuaries and oceanic environments; maintenance dredging and material disposal; engineering methods used to analyze and mitigate the effects of marine pollution; and environmental ethics, economics and regulatory statutes. Prereq: senior standing as an engineering major or approval.

EN412: Ocean Environmental Engineering II (3-0-3). Basic principles and current issues in environmental engineering as applied to the ocean environment are introduced. Principal focus shall be on Ocean Resources: Their Identification, Recovery and Utilization. Topical coverage includes the technological aspects of alternate energy sources; deep-ocean oil and gas recover; desalinization; dredging and uses for dredge spoil; mineral exploitation; ocean depositories; wetlands, reefs and other coastal developments; and environmental economics, ethics and regulatory statutes. Prereq: senior standing as an engineering major or approval.

6. CONCLUSIONS

The last two offerings of this environmental engineering course in the Systems Engineering Department at the U.S. Naval Academy has been a complete success as evidence by instructors comments and students course critiques. Students have demonstrated a good level of mastery of

the course material and have received significant design experience. The students enjoyed the hands-on labs, research projects, and giving presentations. Much of the laboratory experience they received in this course can be of immediate use for their project in their senior capstone design course.

7. REFERENCES

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[3] MATLAB User's Guide, The Mathworks, Inc., Natick, MA, 1990.

[4] Proakis, J.G., and Manolakis, D.G., Digital Signal Processing, Prentice-Hall Inc., 1996.

8. BIOGRAPHICAL INFORMATION

GEORGE E. PIPER is an Assistant Professor in the Weapons & Systems Engineering Department at the United States Naval Academy. He holds a B.S., M.S. and a Ph.D. in mechanical engineering from Drexel University. Prior to joining the Naval Academy faculty, Dr. Piper was a senior member of the technical staff at Martin Marietta's Astro Space Division. He is a licensed Professional Engineer. Dr. Piper's current interest include active magnetic bearings and their application to noise and vibration control. He also keeps an active interest in environmental engineering issues.

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