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# Interdisciplinary Team-Teaching Experiences of a Computer and Nuclear Energy course designed for Non-Nuclear Engineering Students

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## Abstract

*This paper discusses an experience and assessment of an interdisciplinary computer and nuclear safety course which was developed and offered to non-nuclear engineering students. Computer control and nuclear energy safety were the two areas addressed. A unique interdisciplinary team-teaching model was applied to teach the two areas. The university professors taught the sections dealing with computer dependable systems with emphasis placed on reliability and safety while the guest speakers focused on topics related to nuclear energy safety and security. This teaching model allowed an institution without a nuclear engineering program to offer nuclear-related courses. The overall survey results from the offerings of the course showed a very positive response from the majority of the students.*

Keywords - interdisciplinary course; nuclear safety; computer related accidents; team teaching; hardware/software diversity

## 1 Introduction

The rapid adoption of computer control systems for nuclear power plants has resulted in the reliability of computer hardware and software becoming an important component of nuclear plant design, operation, and maintenance. Security and reliability of hardware and software plays a crucial role in the safety of nuclear plants. The need for safe and reliable computer based control systems has created new and greater concerns that were not experienced during the age of analog control systems. Because of these concerns, the failure of a single component, such as a defected control logic device or faulty coding procedures or subroutines, could disable major functions of the system and cripple the successful operation of any nuclear plant. This critical situation requires a timely supply of capable engineers who can deal with the new issues of the safety and reliability of computer control systems in nuclear plant operations. There are numerous practical challenges related to teaching nuclear engineering and science courses to non-nuclear students, especially in an institution with no programs related to nuclear engineering.

To address the shortage of new engineers in the emerging issues of computer control and to provide a broad interdisciplinary knowledge to general engineering students, a new teaching model was needed to develop "a more comprehensive suite of mechanisms that can be implemented to diversify and to add excitement to the nuclear field" [1]. A new course development project was proposed to the U. S. Nuclear Regulatory Commission (NRC) with aims to diversify and to add excitement for non-nuclear engineering students to the nuclear engineering field [2]. The project was granted and a team-teaching model was adopted and organized, comprising of the project investigators teaching computer safety methodologies and the nuclear experts focusing on areas dealing with nuclear engineering safety. The new course was developed and offered with the team-teaching model. The NRC guest speaker series formed with volunteer nuclear experts with diverse backgrounds greatly helped to develop the interdisciplinary nuclear course.

## 2 Course Contents Development

The team-teaching based new course was developed with emphasis on organization with defense-in-depth concepts; emphasis on hardware/software diversity relevant to digital instrumentation and control (I&C) and regulations, cyber-security, and safety within nuclear energy organizations.

### 2.1 Course Contents for Computer Safety

Digital Instrumentation and Control: A nuclear power plant has a central control room where operators collect, detect, analyze, monitor, and verify information from multiple indicators and alarms. The majority of I&C systems in today's nuclear plants are beginning to apply advanced I&C technology in all aspects of operation and maintenance.

Software Errors: Software used in nuclear plants must be ensured that required actions are taken to avoid unnecessary fixes. A number of software errors have been detected in the operation of nuclear plants. It has been documented that the failures due to software errors occurred as often as those derived by hardware failures. The major concern with software errors are that these errors tend to be difficult to prevent because they may occur only when an unusual set of inputs exist.

Computer Technology and Common Mode Failure: Computer control system faces safety issues in that common mode failures may fail even redundant safety systems compromising safety detecting functions [3]. Since software based I&C is known to be vulnerable especially to common-mode failure, the system requires deploying different diversification strategies in the applications with also redundancy in the hardware and operating systems.

Defense-in-depth and Diversity: All safety activities are subject to layers of overlapping provisions so that if a failure occurred it would be compensated for or corrected without causing harm to individuals or the public at large. The defense-in-depth concept, when properly applied, ensures that no single human or mechanical failure could lead to injury of the public and that even combinations of failures which are only remotely possible would lead to little or no injury. In the design diversity approach, multiple versions of software of different algorithms can be written for the same function. For hardware, processors and operating systems from completely different architectures and designs can be employed for the same function [4].

Hardware Diversity Kit: The hardware diversity kit is composed of a nuclear reactor event scenario generator and a set of diverse architectural hardware which individually responds to the scenarios [5]. For coding each of the platforms, students will be required to use different behavioral requirements for the same function for the scenario.

## 2.2 Course Contents for Nuclear Energy

NRC Overview: This topic covers the mission and the major activities of NRC in the areas of material, reactors, oversight, emergency responses, and new researches.

Nuclear Reactor Concepts: Commercial nuclear power plant design categories are discussed covering pressurized water reactors and boiling water reactors.

Security and Safeguard of Nuclear Power Plant: Nuclear power plants must be both safe and secure. Safety refers to operating the plant in a manner that protects the public and the environment. On the other hand security refers to protecting the plant by using trained staff, equipment and other methods from intruders who wish to do harm.

Licensing Process: The steps and the level of details regarding the licensing are discussed for stable and predictable licensing process so that safety and environmental issues are resolved before authorizing construction. The involvement of timely and meaningful public participation is provided.

Power Generation: Design considerations and regulations are discussed for technical specifications and environmental qualification as well as station blackout and maintenance rules. Worldwide industry trend is also presented.

Digital System Safety and Cyber-Security: This is to ensure digital safety system reliability, availability, and integrity for non-malicious and malicious events. The topic talks about the history of digital system safety and cyber-security; overview of the current cyber- security program and digital system safety review; and the regulatory developments regarding cyber security.

Severe Accident Analysis: This topic compares the design basis accidents and severe accidents in terms of accident severity as well as the station blackout and plant response.

New Rectors: This topic discusses the new and small modular reactors with specific features and safety systems.

# 3 First Course Offering

The new course, officially numbered and titled as “EECE499 Computers and Nuclear Energy” at Howard University, was offered for the first time in fall 2011 for all engineering students of both undergraduate and graduate status. The course was subsequently offered in the fall 2012 and 2013.

## 3.1 Course Offering Format

The course was conducted with a weekly schedule covering the two subjects (Computer control and nuclear energy safety) simultaneously. Further details of the class, including the materials covered, are available from the website of the project at http://www.mwftr.com/NuclearSafety.html.

## 3.2 Survey and Assessment

For the 2011, class a total of 26 engineering students, 19 undergraduate (of electrical, computer, and chemical engineering) and 7 graduate (of electrical engineering), out of 28 students enrolled in the class completed a class survey and indicated their perception on the course. Overall, the students expressed very positive attitudes in taking the course. In particular, the students were very satisfied with the format of the interdisciplinary team-teaching and the team of lecturers – their professor on computers safety and the guest speakers on nuclear energy. Overall, they rated the course quite favorably in terms of their (a)understanding in computer mistakes and errors (b) understanding nuclear energy and safety, (c) understanding the use of computer in nuclear area, (d) increase in their interests in safety-critical computer systems, and (e) meeting their expectation of the course.

Tables (1-3) show (a) Lectures presented by the NRC and HU faculty members, (b) the overall average survey of the course (1-5 with 5 being the highest score), and (c) the students wish list for future offerings

Table 3 shows the Students Wish-List (Top 5). This List is being addressed in future offerings of the course.

# 4 CONCLUSIONS

This paper described an NRC sponsored project of teaching computer safety for digital I&C in nuclear plants for non-nuclear engineering students at Howard University by applying a team-teaching model to effectively cover two subjects in safety concerns: computer control and nuclear energy. The project investigators and the NRC guest speakers covered the two subjects concurrently for the developed course. The majority of students of the course agreed that the course met their expectation and increased their knowledge and understanding of the subjects. This project, when further enhanced, would meet the demand not only for training students but also eventually for diversifying workforce in computer and nuclear safety.

**Table 1**
**EECE499 Computers and Nuclear Energy - Lecture Presentations (NRC/Faculty)**

a) Computers and Risk (Faculty)
b) NRC Overview (NRC)
c) Introduction to Nuclear Reactor Concepts (NRC)
d) Security and Safeguards of NPP (NRC)
e) Software Reliability in Safety Critical Systems (Faculty)
f) Software Failure Data Analysis (Faculty)
g) Nuclear Criticality and Nuclear Engineering (NRC)
h) Defense in depth (Faculty)
i) Power Updates (NRC)
j) Diversity for Safety Critical Systems Applications (Faculty)
k) Licensing Processes (1) and (2) (NRC)
l) IEC Standards of Safety – Critical Systems (Faculty)
m) Cyber-security (NRC)

**Table 2**
**EECE499 Computers and Nuclear Energy - Student Survey (1-5 (5 being the highest score))**

**Part I**

a) Students understanding of computer errors/failures (4.89)
b) Students understanding of nuclear energy and safety (4.56)
c) Students understanding of the use of computers in the nuclear industry (4.44)
d) Students interested in safety critical systems (4.56)
e) Students interested in the nuclear energy and safety (4.00)
f) Students interested in employment in the nuclear energy field (3.89)
g) Students expectation of the course (4.78)

**Part II**

a) Content and presentation on safe computing (5.00)
b) Adequacy of assignment on computers (4.89)
c) Amount of knowledge gained on safe computing (4.67)
d) Content and presentation on nuclear energy (4.67)
e) Knowledge gained on nuclear energy (4.56)
f) Level of comfort in class lectured by team teachers (4.89)

**Table 3**
**EECE499 Computers and Nuclear Energy - Student Wish List**

a) More Hands-on activities
b) More on-site visits – especially to nuclear power plants
c) More utilization of Multimedia CDs
d) More software coding examples
e) Earlier involvement during the semester with the Hardware Diversity Kit

## 5 Acknowledgment

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