AC 2008-1443: ESTABLISHMENT OF UNDERGRADUATE RADIOCHEMISTRY AT FLORIDA MEMORIAL UNIVERSITY: A COOPERATION WITH THE NUCLEAR AND RADIATION ENGINEERING PROGRAM AT THE UNIVERSITY OF TEXAS AT AUSTIN

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Development of a Nuclear Certificate for Nuclear Safety, Nuclear Security, and Nuclear Environmental Protection Within a Mechanical Engineering Department

Introduction

Teaching and research initiatives in nuclear education have dramatically veered away from nuclear power operations over the past three decades. With the advent of a real change in delivering economically competitive electricity base loads in the nuclear industry, global warming, and a transformation in public perception, including politicians, on the requirement for greenhouse gas free electricity production, there is a clear need to have academic programs to support the US NRC and the nuclear power industry. A nuclear technical option at The University of Texas at Austin has been in existence for fifty years. The earliest known course was Nuclear Reactor Operation and Maintenance and was first offered in 1957. Nuclear Engineering became an option in Engineering Science in 1960 and in Mechanical Engineering in 1970, where it is currently administered. In August 1963, the TRIGA nuclear reactor went critical at 10kW using fuel loaned from the U.S. Government. In 1968, the power was upgraded to 250 kW and then upgraded again in 1992 to 1,100 kW at a different site; the Nuclear Engineering Teaching Laboratory (NETL). Throughout its long history, the nuclear program has had a commitment to educating the brightest students in the United States and abroad. This dedication which continually grows stronger now as the program has expanded to encompass health physics, radiation engineering, research reactor beam port experiments, radioactive waste management and reactor and computational nuclear engineering, homeland security and non-proliferation. As a result of the ever broadening educational and research needs, ten years ago the nuclear program changed its name to Nuclear and Radiation Engineering to better reflect its new directions. In spring 2007, we were funded by the Nuclear Regulatory Commission to implement at new undergraduate technical option in the Nuclear and Radiation Engineering Program at The University of Texas at Austin

Objective

The overall objective is to provide: (1) a Nuclear Certificate geared towards undergraduate students in engineering and individuals in the nuclear industry consisting of courses in nuclear safety, nuclear security, nuclear environmental protection, and reactor operations including 15 overall credits with 3 credits from a chosen graduate course where such an opportunity will serve as a bridge for undergraduate students to consider graduate education; (2) an opportunity for students to train on The University of Texas TRIGA reactor and achieve NRC Reactor Operator license; and (3) an avenue to encourage internships at the NRC and nuclear power plants. These outcomes will have the benefit of creating a pipeline of well qualified students to the Nuclear Regulatory Commission (NRC) (especially to serve NRC Region 5), and to the nuclear industry for employment including the seven newly planned nuclear reactors in the state of Texas.

Education Team

There will be several members on the team. The PI, Dr. Landsberger has been the Coordinator of the Nuclear and Radiation Engineering Program for the past ten years and has 20 years of teaching and research experience in health physics, radioactive waste management and radiochemistry. He is also the recipient for the second time of the DOE Radiochemistry and Educational Award Program (REAP). Dr. Landsberger is also the beneficiary of the Glenn Murphy Teaching Award from the Nuclear and Radiological Division of the American Society of Engineering Education and was just given the Holly Compton Award for Nuclear Education by the American Nuclear Society. Dr. Landsberger along with a graduate student will develop the *Nuclear Environmental Protection* course.

Dr. Steven Biegalski is the Director of the Nuclear Engineering Teaching Laboratory and has several years of industrial experience along with his PE Certification in Nuclear Engineering. He will lead the development of the *Reactor Operations* course along with Michael Krause, the reactor manager.

Dr. Elmira Popova is in the Mechanical Engineering Operations Research and Industrial Engineering Program and has many years of experience in probabilistic risk assessment (PRA). She currently has an NSF award in Risk Informed Nuclear Asset Management for Electric and Nuclear power generation. Along with Dr. Kendra Foltz-Biegalski she will develop the *Nuclear Safety and Security course.* Dr. Elmira Popova headed up the Risk Informed Asset Management (RIAM) program that is a joint effort between the Operations Research and Industrial Engineering Graduate Program at The University of Texas at Austin, the Risk Management Group at South Texas Project Nuclear Operating Company (STPNOC), and the Nuclear Asset Management Program at the Electric Power Research Institute (EPRI). The main objective of the RIAM program is: to make optimal risk-informed decisions at both operational and executive management levels by taking into account budget, internal project dependencies, outage duration, and regulatory safety constraints; to appropriately model and include the uncertainty related to rates of return on investments, energy prices, failure mechanisms, and costs for replacement and spare parts; and to provide decision-makers quantified feedback on decision-making performance. She has very strong ties to with the South Texas Project nuclear power plant that have funded her research program continuously since 2004.

Dr. David Morton, Professor in the Mechanical Engineering Operations Research and Industrial Engineering Program, is a collaborator on the RIAM program. He will not be specifically involved in course development but will interact with Dr Elmira Popova.

For the past ten years, Dr. Kendra Foltz-Biegalski has been involved in non-proliferation and algorithm development in environmental fission product identification and has developed teaching tools in these areas. For several years, she was an expert scientist for the US Department of State Verification and Monitoring Task Force committee which helped develop US policy on verifying and monitoring for nuclear weapons tests. Dr. Foltz-Biegalski developed the algorithms still in use today at the International Data Center in Vienna, Austria for detecting and quantifying environmental radioxenon isotopes. She also has a PE license in Nuclear Engineering. Dr. Foltz-Biegalski will develop the security portion of the *Nuclear Safety and Security* course.

Michael Krause has more than 23 years experience as a TRIGA reactor manager, has trained many students and visiting scientists for their RO and SRO licenses, and has been involved in reactor engineering laboratory instruction. He will work closely with Dr. Biegalski in the development of the *Reactor Operations* course.

Sean O'Kelly is the Associate Director of the TRIGA reactor and he has many years of experience in management, security issues, training of personnel for reactor operations and in dealing with the NRC. He will be an advisor to several aspects of this educational endeavor in operations research.

The team is well suited to pursue revitalization for curriculum development. We believe there is a strong need to have a program in place at the earliest possible time to begin the pipeline of educating students with this type of academic experience for the NRC and the nuclear industry. We envisage an intensive one-year preparation to inaugurate this new Nuclear Certificate in the fall 2008 academic semester. With the planning of seven new nuclear plants in Texas we feel this new program will go a long way to help fulfill the needed workforce.

Course Development Overview

The four required undergraduate courses will include *Introduction to Nuclear Power Systems, Nuclear Safety and Security, Nuclear Environmental Protection, and Reactor Operations*. Introduction to *Nuclear Power Systems* is already in place, covers basic nuclear reactor theory, and will be the gateway course for the Certificate Program. Some modifications to this class will be implemented to address the needs of the Certificate Program.

Nuclear Safety and Security will cover PRA models and nuclear non-proliferation. PRA methodologies taught in this course will include: failure classifications, failure modes, effects, and criticality analysis (FMECA), fault and event trees, and reliability block diagrams. Students will be introduced to techniques for estimating the chances of events that, if they occur, could lead to an accident, and how to forecast the consequences of such event occurrences. In addition, specific areas the Code of Federal Regulations will be discussed such as 10 CFR 73, 74, and 75. The nonproliferation part of the course will cover US and international laws, treaties, agreements, and organizations as well as the technical aspects of environmental detection and transport modeling of radionuclides of interest, qualitative and quantitative methodologies for modeling proliferation resistance of nuclear fuel cycles, and current topics of concern, such as border security and transportation.

The *Nuclear Environmental Protection course* will include radioactive waste as well as, the nuclear fuel cycle including reprocessing, environmental pathways (such as air dispersion and ground water modeling) and the inclusion of 10 CFR 61, 62, and 63. *Reactor Operations* will review the basics of nuclear reactor kinetics, reactor procedures, and will review 10 CFR 19, 20, 50, 51, 52, 54, and 55. Students in the *Reactor Operations* course will be introduced to material requisite for taking the NRC Reactor Operator License exam. Only students with an ability to contribute to the operations of the TRIGA reactor at NETL will be given the chance to take the exam.

One 3-credit graduate course will also be required for students to obtain the Nuclear Certificate. The students will be able to choose among courses already in place at The University of Texas at Austin including *Reactor Power Systems, Nuclear Reactor Laboratory,* and *Nuclear Reactor Theory*.

Out of the courses mentioned above, *Nuclear Safety* and *Security* and *Reactor Operations* will have to be completely developed for the Nuclear Certificate Program. The *Nuclear Environmental Protection* course will be adapted from the current *Radioactive Waste Management* course and will include about 50% new material. We believe the inclusion of specific 10CFR sections to the program is a vital component to the educational and training experience to the students.

The main focus of the development is to have an integrated approach to the Nuclear Certificate Program with careful planning of the content and sequence of courses to be taken within the Mechanical Engineering Department. All the students will be closely mentored and directed to opportunities for scholarships from Nuclear Academy of Nuclear Training, the American Nuclear Society, and the Department of Energy. We will further point out the opportunities for internships at NRC, nuclear power plants and allied supporting industries. There is also a Radiation Physics technical option within the Physics Department where the students are required to take 13 hours of nuclear and radiation engineering courses with the Mechanical Engineering Department. There is an excellent opportunity for recruiting these students as well. Below is a detailed description of the above mentioned courses.

1. Introduction to Nuclear Power Systems

This course is an introduction to the concepts of nuclear engineering and is the first course to be taken in the sequence. The course starts with an introduction to nuclear structure and nuclear decay. The structure of the atom is discussed along with binding energy, radioactive decay and the calculation of Q values. Basic nuclear reaction calculations are covered next including reaction rates and calculations of the neutron multiplication factor. The subsequent course section reviews discussion of how to create power with nuclear power covers nuclear reactors, nuclear batteries, fusion systems, and radioactive waste management. The course finalizes with diffusion theory calculations.

A distance learning laboratory is conducted at the end of the course that utilizes The University of Texas at Austin TRIGA reactor. This laboratory examines the time dependent reactor kinetics involved in prompt jump and prompt drop reactivity insertions. Students in the classroom observe reactor behavior and collect data real-time via remote connection to a computer with streaming data from the nuclear reactor.

An outline of the course is as follows:

A. Introduction to Nuclear Structure and Decay
   a. Nuclear Particles and Nuclear Notations
   b. Nuclear Reactions
   c. The Mass-Energy Relationship and Binding Energy
   d. Radioactive Decay
   e. Q-Values

B. Basic Nuclear Reaction Calculations
   a. Atom Density and Cross Sections
   b. Radiation Interactions with Matter
   c. Chain Reactions and k
   d. Six Factor Formula

C. Power Generation with Nuclear Power
   a. PWRs and BWRs
   b. Advanced Reactor Design
   c. Nuclear batteries

d. Fusion Systems
e. Radioactive Waste Management

D. Diffusion Theory
a. Neutron Flux and Fick's Law
b. Diffusion Equation
i. Diffusing media with nuclear source
ii. Bare reactor systems
iii. Time dependent systems
c. Distance learning lab on prompt jump and prompt drop

2. Nuclear Safety and Security

There are two major sources of risk in nuclear power generation: one that originates while running the plant and a second one during the process of disposing the spent nuclear fuel. Proper modeling and accounting for risk is crucial to ensure the safety of the supporting personnel and surrounding areas.

The purpose of this new course for the Mechanical Engineering undergraduate program is to teach the engineering students (with a technical minor in Nuclear Engineering) the basic tools and methods for probabilistic risk and safety assessment in nuclear power plants. The proposed teaching structure is a combination of lectures that present the theory, lab exercises with real data and problems taken from South Texas Project (STP), a nuclear power plant based in Bay City, Texas, and guest speakers from the Risk Management group at STP. The instruction will take place from the University of Texas at Austin classrooms equipped for distance learning. This will accommodate students who are not full time on campus and will allow for speakers from STP (and other agencies/industries) to participate in the course instruction and observation.

The course development will require the involvement of one graduate student. He/she will work on setting up the lab exercises that stem from real problems and data. The graduate student will communicate with staff in Risk Management and Systems Engineering at STP on a regular basis to define relevant problems, gather the necessary data, and prepare the exercises. The student will also participate in the preparation of the lecture materials necessary for the distance learning environment.

The descriptions of the basic teaching modules follow:

A. Basic risk concepts and analysis

This module will provide the introduction to reliability, safety, hazard, and risk concepts. The definition and measures of risk, public risk and attitude, societal risk management, and risk legislation will be covered. The notion of risk aversion is important since different risk tolerances can lead to different strategies/system designs. The students will learn a variety of risk-aversion mechanisms and how to set up safety goals.

B. Probabilistic Risk Assessment (PRA)

Probabilistic risk assessment (PRA) is a collection of analysis techniques that serve to identify potential accident sequences and assess the likelihoods and consequences of those accident sequences. First developed and applied in the aerospace industry, PRA methods have been increasingly used as a safety management tool in the nuclear power industry through the 1980's and 90's. This capability is of central importance in the domestic nuclear power industry in the new century. PRA provides answers to four important questions: (i) What can go wrong? (ii) How likely is it? (iii) What are the consequences? and (iv) How do uncertainties impact the above answers?

There are three levels of PRA analysis in the commercial nuclear power industry: Level 1, Level 2, and Level 3. Level 1 consists of an analysis of plant design and operation focused on the accident sequences that could lead to a core damaging event, their basic causes and their frequencies. Key figure of merit is the Core Damage Frequency (CDF). Level 2 consists of a Level 1 PRA plus an analysis of the physical processes of the accident and the response of the containment. The key figure of merit is Large, Early Release Frequency (LERF). Level 2 predicts: the frequencies of core damage by sequences, time and mode of containment failure, and inventories of radionuclides released to environment. Level 3 consists of a Level 2 PRA plus analysis of the transport of radionuclides through the environment and assesses the public health and economic consequences of the accident. Key figure of merit are fatalities (both early and late).

PRA analysis requires basic knowledge in probability and statistics. This module will start with building the necessary probability background by teaching what is: random experiment, sample spaces and events, Venn diagrams, Boolean algebra, definition of probability, equally-likely probabilities vs. subjective (Bayesian) assignment of probabilities, conditional probabilities.

The second part of this module will consist of introduction to PRA: initiating events, risk profiles, nuclear power plant PRA – WASH-1400 and the update NUREG-1150. Next, the description of the event sequence diagram (ESD) approach to PRA model construction will be considered. Here, the types of end states, and the accident scenarios in commercial nuclear power plants will be taken into account. Case studies for each of the three PRA levels will be done jointly with South Texas Project Risk Management group.

C. System models and analysis

The main topics covered are: commercial nuclear plant "system" description (what does "system mean"?), systems and interfaces, failures and failure classification. The students will learn the failure modes, effects, and criticality analysis and how to construct a system fault tree model from plant information (typical drawings, typical commercial plant documentation.). The notion of fault tree building blocks, top events, and cut sets and path sets will be introduced. Generation of the minimal cut and path sets is crucial to assess system's reliability and safety. The students will build them for a real example guided by STP engineers.

The event tree analysis is necessary to properly quantify the consequences of an initiating event. The large event tree - small fault tree approach and large fault tree - small event tree approach will be presented and compared. The limitations of the commercial solvers will be discussed. The reliability block diagram will be taught as one of the required tools for system structure analysis. The lower and upper bounds for system unavailability using the inclusion - exclusion approach and partial minimal cut sets and path sets will be computed as part of this teaching module.

D. Uncertainty modeling, data, and data update with plant experience

Proper modeling of uncertainties is one of most important steps in PRA. The nuclear power plant is a collection of systems with high reliability, i.e. they do not fail often. As a result few failure data are available for analysis. Classical statistical techniques rely on large volume of data and will not be (in general) applicable in this case. In addition, the nature of the maintenance performed can change the future failure behavior of the underlying systems. The students will learn two basic maintenance policies that lead to either repair-to-failure process or repair-failure-repair process. The constant failure rate and repair rate model will be discussed. The following collection of distributions largely used in the nuclear industries will be covered in detail: Exponential, Gamma, Beta, Lognormal, Weibull, Binomial, and Poisson.

There are two main sources of data – local plant data and industry (generic) data. The limitations of data and data sources will be discussed. The combination of the plant specific data and using generic data as a prior via Bayesian modeling will be presented. In particular, the Department of Energy generic prior data study[1] will be implemented as one of the lab exercises.

The nature of the failure data is unique – the student will learn the notion of complete and censored data sets. Two estimation methods will be covered – nonparametric and parametric. The nonparametric methods include: empirical distributions, Kaplan-Meier estimator of the reliability function, and the total time on test plot. The parametric method of maximum likelihood will be studied and applied for the analysis of a real data set (using a statistical software package).

A certain amount of time will be spent to model and analyze dependent failures and common-cause data. Examples of common cause data modeling and propagation of uncertainty will be provided. The students will learn how to obtain common-cause cuts sets. The students will also learn about sources of epistemic uncertainty in PRA modeling (in addition to aleatory uncertainty discussed above).

E. Human reliability

The reason for most of the accidents in nuclear power plants is human error. In this module the students will learn how to classify human errors for PRA: before an initiating event and during an accident. The notion of performance shaping factors (PSF), both internal and external will be studied. The human-performance measured by PSFs in terms of error rates and stress levels, response time, and recovery action will be discussed.

F. Nuclear Security and Nonproliferation Topics

As part of the *Nuclear Safety and Security* course, three to four weeks of lectures will focus on nuclear security and nonproliferation topics. Topics may be expanded according to expressed interest of the students as well as current events. The use of software for isotope detection and various modeling applications is integrated within this part of the course. Homework will consist of technical problem solving, including the application of software and modeling algorithms, as well as a research paper on a selected topic of interest. An exam testing students' mastery of these subjects will be given at the end of this lecture section.

a. Background
b. Nuclear security
    1. International treaties and agreements
        i. Non-Proliferation Treaty (NPT)
        ii. Comprehensive Nuclear Test-Ban Treaty (CTBT)
        iii. Strategic Arms Reduction Treaty I and II (START)
        iv. Proposed Fissile Material Cutoff Treaty
        v. Nuclear Weapon Free Zones
        vi. US/Russia Collaborations
    2. International Organizations
        i. CTBT Organization (CTBTO)
        ii. International Atomic Energy Agency (IAEA)
        iii. Convention on the Physical Protection of Nuclear Materials (CPPNM)
        iv. Country-specific efforts
    3. U.S. Laws and Organizations
        i. Department of Energy (DOE), National Nuclear Security Agency (NNSA)
        ii. Nuclear Regulatory Commission (NRC), pertinent Code of Federal Regulations(10CFR)
        iii. Environmental Protection Agency (EPA)
        iv. Department of Defense (DOD), National Data Center (NDC) at the Air Force Technical Applications Center (AFTAC)
    4. Detection and Enforcement
        i. Air sampling Via Fly-Overs
        ii. Onsite Inspections
        iii. Remote Sensing
            1. CTBTO Global Detection System
            2. National Efforts
            3. Satellite Images
            4. Detectors
            5. Data Analysis/Software
        2. Ramifications of positive detection
    5. First Responders
        i. Planning
        ii Organizations Involved
        iii. Actions
    6. Current Topics of Concern
        1. National
            1. Border Security
            2. Export control and Regulations

3. Transportation: Airplane, Boats, Road Vehicles, Underground Systems (Subways)
4. Technology development

2. International
    1. Russia
    2. China
    3. Iran
    4. North Korea
    5. Pakistan & India

c. Nuclear fuel cycle

1. Definition
2. Facilities Involved, Including Temporary and Permanent Spent Fuel Storage
3. Chemical and Physical Forms of Uranium and Plutonium With the Nuclear Fuel Cycle
4. UREX process
5. PUREX process
6. Nonproliferation Assessment Tool (NAT) Software, Integrated with ORIGEN
    a. Security and Proliferation Risks Associated with the Nuclear Fuel Cycle

d. Proliferation Resistance (PR)

1. Definition
2. Applications
3. Qualitative Methods of Determining PR
4. Quantitative Methods of Determining PR
    i. Expert Group Delphi
    ii. Comparative Value Measure
    iii. Probabilistic Risk Analysis
    iv. Risk/Consequence Analysis
    v. Multi-Attribute Utility Analysis

3. Reactor Operations

The *Reactor Operations* class to be developed will encompass the operating principals and regulatory requirements for operating a nuclear reactor. Prior to taking this course the student should possess basic mechanical and nuclear engineering knowledge either gained through experience or developed by taking basic mechanical engineering coursework and the *Introduction to Nuclear Power Systems* course. The *Reactor Operations* course when coupled with selected information covered in other courses which comprise the Certificate Program, including topics covering nuclear Facility Safety Analysis Report (FSAR), security plans, emergency plans, radiation protection, and environmental protection, will provide individuals pursuing a license to operate a research reactor or who intend to take the generic fundamentals exam portion of the nuclear power plant operator exam. Additional requisite knowledge of site and reactor facility specific information, which is also required knowledge for an operator licensing exam, will not and cannot be covered in detail by this course because it is so site-specific. Where possible, some information typical of research reactors and/or commercial power plants will be reviewed to provide general systems knowledge.

The course format will consist of formal classroom lectures presented in a distance learning configured classroom interspersed with laboratory sessions which will demonstrate and emphasize materials discussed in the lectures. The laboratory sessions will utilize the University of Texas TRIGA Research Reactor and if possible one of the Texas commercial nuclear power reactor. The laboratory sessions using the TRIGA research reactor will be conducted either on site in the facility control room or in a distance learning classroom utilizing live data from the operating reactor via a network feed.

Proposed topics which will be covered in the class include:

A. Introduction
B. Reactor Theory
   a. Neutron Sources
   b. Neutron Life Cycle
   c. Reactor Kinetics
   d. Reactivity
   e. Poisons
C. Reactor Designs
   a. TRIGA research reactors
   b. Boiling Water Reactors
   c. Pressurized Water Reactors
   d. Generation III reactor Designs
   e. Generation IV reactor Designs
D. Control, Operation, and Monitoring Systems
   a. Reading System Diagrams
   b. Human Factors
   c. System Calibration, Surveillance, and Maintenance
E. Reactor Facility licensing requirements specified in 10CFR Part 50
   a. Typical License Content
   b. Technical Specification Content
F. Operator licensing requirements specified in 10CFR part 55
   a. NUREG-1478 "Non-Power Reactor Operator Licensing Examiner Standards"
   b. NUREG-1021, "Operator Licensing Examination Standards for Power Reactors"
G. Operations
   a. Subcritical Multiplication
   b. Fuel Loading and 1/M
   c. Control Rod Calibrations
   d. K_{excess} and Shutdown Margin
   e. Reactor Power Calibration
   f. Reactivity Coefficients and Feedback from Secondary Systems
   g. Fission Product Poisons

4. Nuclear Environmental Protection

Currently there are two courses in the Nuclear and Radiation Engineering Option titled *Radioactive Waste Management* and *Radiation and Radiation Protection*. The new proposed course in Nuclear Environmental Protection will incorporate approximately 50% of the current modules of *Radioactive Waste Management*, while introducing new aspects of environmental protection. A detailed description of the proposed new course is given below

A. Radiation and Radioactivity
   a. History
   b. Naturally Occurring Radiation
   c. Alpha, Beta and Gamma Decay
   d. Half-Life
   e. Radioactivity Equilibrium
B. Interaction of Radiation and Matter
   a. Energy Transfer Mechanisms
   b. Beta Range
   c. Alpha Range
   d. Gamma Ray - Photoelectric, Compton Scattering, Pair Production
C. Radiation Dosimetry
   a. Absorbed Dose
   b. Exposure Unit
   c. Rad/Roentgen
   d. KERMA
   e. Specific Gamma-Ray Emission
   f. Beta Contamination
   g. Internally Deposited Isotopes
D. Instrumentation
   a. Alpha
   b. Beta
   c. Gamma
   d. Personnel monitoring
   e. Environmental monitoring - air, water and soil sampling
E. Biological Effects
F. Shielding –
   a. Attenuation
   b. Time
   c. Distance
   d. Introductory Mathematical Concepts
G. History of Nuclear Reactors
H. Siting and Regulations
   a. Historical Overview
   b. 10 CFR Part 61, 40 CFR 190, 40 CFR 191,192, 193
I. Radioactive Waste Forms
   a. Nuclear Fuel Cycle
   b. Government Lab

c. Industry
d. Medical
e. Phosphogypsum

J. Low Level Radioactive Waste Management
   a. Waste Class
   b. Compacts

K. High Level Radioactive Waste Management
   a. Reprocessing
   b. Yucca Mountain
   c. Interim storage facility
   d. Waste Isolation Pilot Plant (WIPP)
   e. Low-level RWM-compact with states
   f. Decommissioning of existing reactors

L. Uranium Mill Tailings Management
   a. Potential Hazards and Size Distribution
   b. Soil and Surface Water Contamination
   c. Regulatory Aspects
   d. Work Level Radon related Alpha Particle Emissions

M. Radioactive Materials Transportation
   a. Department of Transport
   b. Packaging
   c. Spent Nuclear Fuel

N. Atmospheric Dispersion
   a. Climate Conditions
   b. Gaussian Plume Model

O. Radionuclide Fate, Transport and Remediation
   a. Conceptual Models
   b. Three Dimensional Ground Water Flow
   c. Retardation Factors and Absorption Processes

P. Environmental Restoration and Remediation
   a. Nuclear Weapons Complex
   b. Regulatory Framework
   c. Clean-Up Technologies

Recruiting Efforts

Recruitment of students will begin during the freshman year in the mandatory Mechanical Engineering Freshman Design course. Students will be introduced to the Nuclear Certificate Program and will be encouraged to consider as part of their undergraduate course of study. High achieving sophomores will be recruited as undergraduate assistants to work at the TRIGA reactor in the NETL. This approach has worked very well in the past to place students in the nuclear industry. There is also a Radiation Physics technical option within the Physics Department where the students are required to take 13 hours of nuclear and radiation engineering courses with the Mechanical Engineering Department. The program will also be advertised in *Nuclear News* and *Nuclear Plant Journal.* A link to this information on the Nuclear Certificate Program will be placed on The University of Texas Nuclear and Radiation Engineering web site.

Recruiting qualified students from underrepresented minorities will also be pursued. The PI has very extensive and ongoing interactions with the UT Equal Opportunity in Engineering (EOE), Women in Engineering (WEP) Program and Texas Research Experience (TREX) programs. Along with Andrea Ogilvie the Director of EOE we will be recruiting students from the Society of Hispanic Professional Engineers (SHPE) and the National Society of Black Engineers (NSBE) both who have strong student representation on campus.

Distance Learning

The Nuclear and Radiation Engineering program has one of the most sophisticated nuclear engineering distance learning courses in the nation [2-17]. There have been many published papers from the participants in this proposal that describe the undergraduate and graduate course developments for distance learning in the Nuclear and Radiation Engineering Program. The program reaches students at the M.S. and Ph.D. levels in industry such as Progress Energy Florida and national laboratories such as Sandia, Los Alamos and Oak Ridge. Other distance learning students are employed by the Air Force, Knolls Atomic Power Limited and Sterigenics (a private company involved in sterilization using accelerators.)

All the courses are available in a live video format that may be downloaded from the university's Blackboard website. All lectures are in Power Point. Lectures are presented utilizing a Smart Board that allows the instructor to electronically write over the slides during class to significantly enhance the quality of instruction. In several cases animations are used to appreciably increase the understanding of complex nuclear phenomena. Thus, many concepts are standalone modules that may be integrated into other courses or given as individual seminars. Development of the new courses will follow the same high standards as achieved for the other courses. A unique feature of this Nuclear Certificate Program will be that it will be offered to workers in the nuclear industry who do not necessarily want to have a full M.S. or Ph.D. degree, but desire to increase nuclear knowledge at their place of work.

At The University of Texas at Austin the PI, Dr. Sheldon Landsberger has successfully given similar courses through The University of Texas Continuing Education Program to Comanche Peak Nuclear Power Plant, Florida Memorial University and Iowa State University. Courses within this program will be offered in a format commensurate with distance learning education. This will allow for participation of off-campus students and specifically targets students who are currently employed full-time. The lectures will be given in a technology classroom with two cameras, multiple monitors, and a large touch sensitive projection computer monitor in the front of the class room. The on-campus students attend class as they would in a normal classroom. Off-campus students may watch the class live on-line or may access the class recording at a later time off the class web site. The class web site is a server for all matters concerning the class. The lectures, video files, homework assignments, grades, and course administrative information may be all accessed on-line.

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