Retaining the Focus:
Nuclear Engineering Research at NC State

NC State University

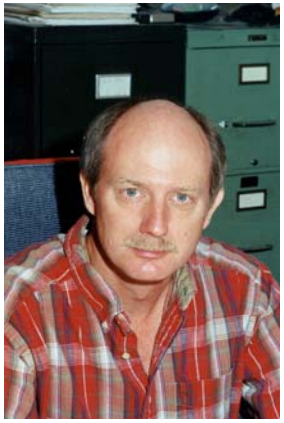
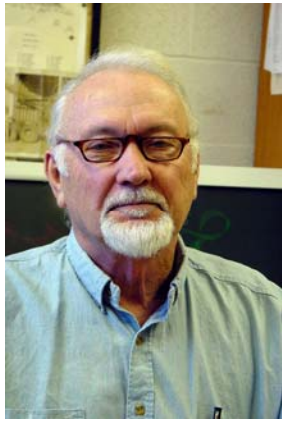
- Carnegie Research I University
- Student Population: ~30,000 Students
  - Undergraduates: ~23,000
  - Graduates: ~7,000
- Faculty Population: ~1,800
- Research Expenditures: ~$440 million
- Federal Research Funding: ~$110 million
- Research Centers: 55 formally established

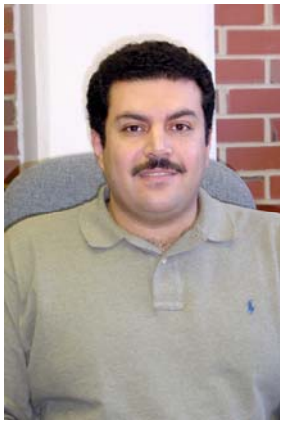
Engineering at NC State

- Enrollments
  - Undergraduate: ~5,700
  - Graduate: ~1,700
- Academic Departments: 12
- Discipline Graduate Degrees: MS 17 PhD 13
- Annual Research Expenditures: $77M
- Research Centers: 19

NC State NE Faculty







Nuclear Engineering at NC State

- Faculty: 11+1 (Vice Chancellor]
- Full-Time Research Staff: 1 [Research Prof.]+4 [Research Associates]+1 [Research Scientist]
- Staff: 4.5 (Administrative) + 7 (Technical)
- Enrollments:
  - Undergraduate: BSNE=112, BSE=12
  - Graduate (MS, MNE & Ph.D.): 44-50
- Annual Research Expenditures: ~$2.4M
- Recently graduate program ranked 6th by USN&WR

Nuclear Engineering at NC State

- Faculty Awards
  - Teaching
    - NC State: Outstanding Advisor (2), Alumni Distinguished Graduate Professor (2), Alumni Outstanding Undergraduate Professor [1], Outstanding Teacher (several times)
    - American Society of Engr. Educators: Glenn Murphy Award (2)
    - American Nuclear Socieity: Arthur Holly Compton Award [1]
    - Edison Electric Institute: Power Engineering Education (1)
  - Research
    - NC State: R. J. Reynolds [1], Alcoa (several times)
    - American Nuclear Society: Mishima (materials), Radiation Science & Technology, Eugene P. Wigner (reactor physics)
    - Department of Energy: E. O. Lawrence (atomic energy)
    - Fellow Grade: Several technical societies

Nuclear Engineering at NC State

- Graduate Student Recognition
- **National Fellowships & Scholarships:**
  - Department of Energy Fellowships: Naval Reactors, AFCI, Nuclear Engineering, OCRWM
  - National Academy of Nuclear Training: Fellowships
  - American Nuclear Society Scholarships: Graduate, Henry/Greebler
- **Awards**
  - American Nuclear Society: Mark Mills (6), Best Papers (national and topical meetings)
  - Patents and Copyrights (software)

Nuclear Engineering at NC State

- Areas of Faculty Research
  - Fission Power Engineering
    - I&C, T-H, Materials, Reactor Physics [terrestrial and space]
  - Plasmas & Fusion Engineering
    - Industrial plasma processing & fusion safety
  - Radiation Applications & Radiological Engr.
    - Nuclear measurement techniques & interpretation, waste management & advanced fuel cycles, medical physics

Nuclear Engineering at NC State

- Formally Organized Centers
- Nuclear Reactor Program
  - Multi-university Southeast INIE Consortium (MUSIC)
- Electric Power Research Center
- Center for Engineering Applications of Radioisotopes
- Academic Center of Excellence in Advanced Modeling and Simulation (now being formed through Idaho National Laboratory relationship]

Nuclear Engineering at NC State

- **Fission Power Engineering Faculty**
  - Dmitriy Anistratov: Reactor Physics & Transport Theory
  - J. Michael Doster: Thermal-Hydraulics and I&C
  - Charles Mayo: Instrumentation & Control
  - K.L. Murty: Materials
  - Paul Turinsky: Reactor Physics & Fuel Cycles

Nuclear Engineering at NC State

- **Plasma & Fusion Engineering Faculty**
- Mohamed Bourham: Industrial Plasmas & Fusion Safety
- John Gilligan: Plasma-Wall Interactions

  Currently Vice Chancellor for Research & Graduate Studies
- Orlando Hankins: Industrial Plasmas

Nuclear Engineering at NC State

- Radiation Applications & Radiological Engineering Faculty
  - Ayman Hawari: Radiation Applications, X-Section Measurements/Calculation, Research Reactor Utilization
  - Michael Doster: Accelerator Target Design for Medical Applications (T-H aspects]
  - Robin Gardner: Radiation Applications in Industry and Medicine
  - Charles Mayo: Radiation Applications in Industry and Medicine
  - Man-Sung Yim: Waste Disposal & Fuel Cycles

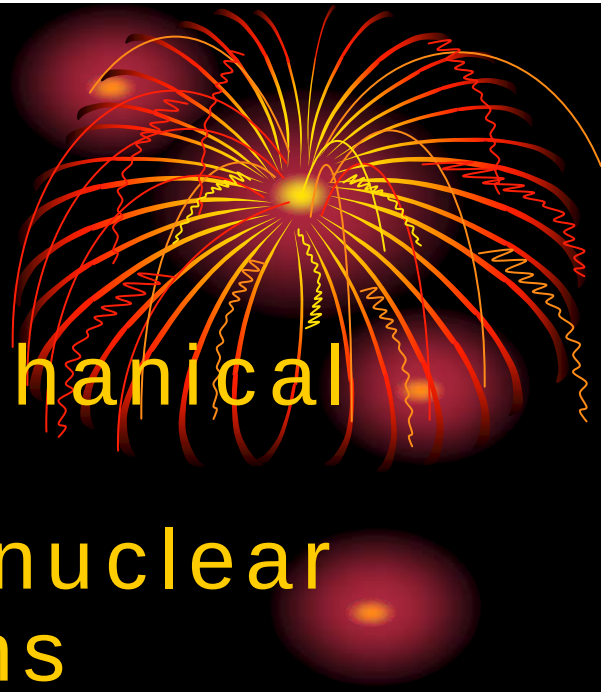
Nuclear Engineering at NC State

- Vacant Position: ???

Research Interests

K.L. Murty
Professor of NE

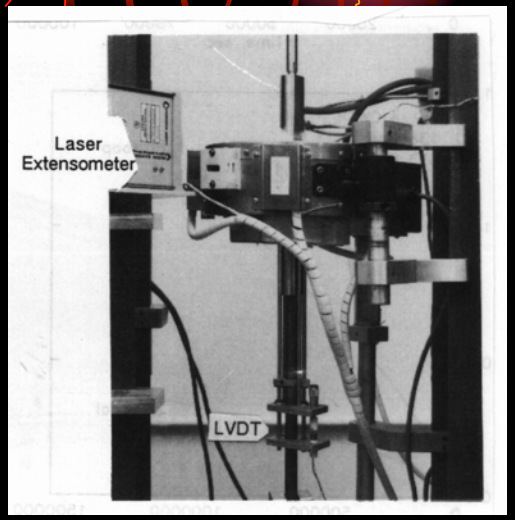
Overall Interests



- Understanding the mechanical behavior of metals in environments found in nuclear engineering applications
- Non-destructive Testing
- Processing & Characterization of nano-structured metals
- Creep resistant high-temperature alloys

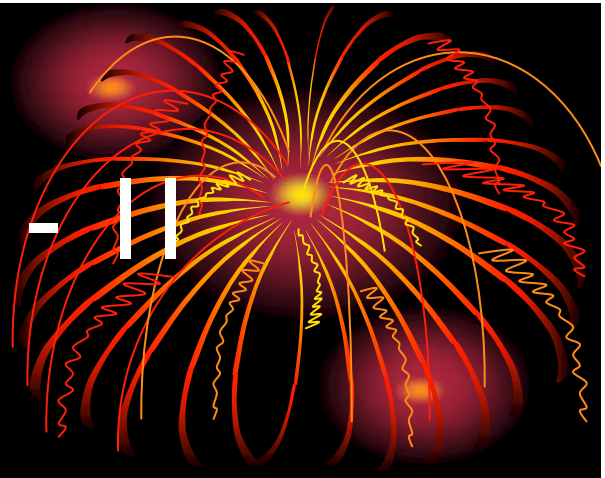
Specific Interests - I

- **Fuel Cladding Materials**
  - Anisotropic Creep Behavior
  - Pellet Clad Interactions
  - Dry Storage Behavior
- **Pressure Vessel Steels**
  - Neutron embrittlement behavior
  - Properties after annealing
  - Embrittlement experimental characterization
- **Non-destructive Test Techniques**
  - Nuclear Magnetic Resonance (Pulse Techniques)
  - Automated Ball Indentation



Biaxial Creep Machine

Specific Interests - II

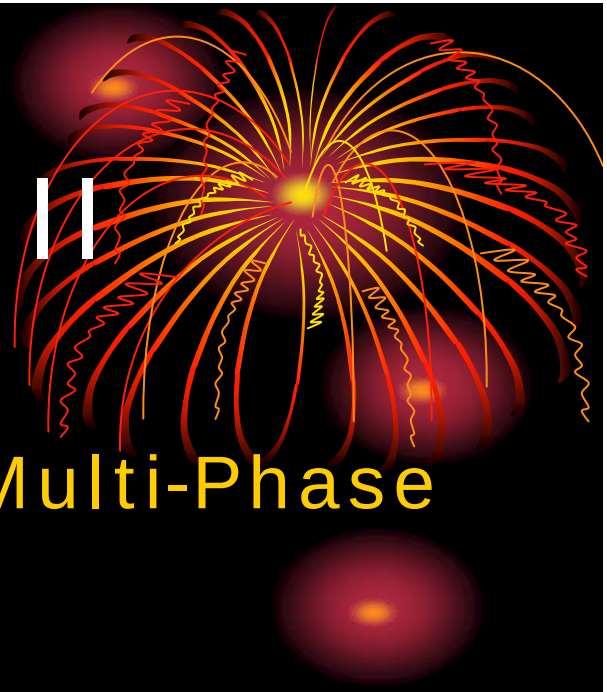


- **Nanostructured Metals**
  - **Deformation Processing (Mechanical Milling)**
  - **Pure Metals and Alloying Effects**
  - **Structural and Mechanical Property Characteriztion – development of small specimen testing**
- **Creep-Resistant Alloys**
  - **Creep Rupture Properties**
  - **Ultra Critical Steam Turbines**
  - **Gen-IV applications**

Current Projects - I

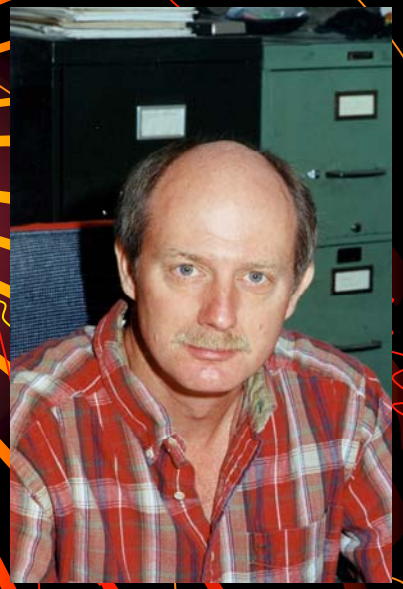
- Deformation Microstructures and Creep Mechanisms in Advanced Zr-Based Cladding Under Biaxial Loading
  - Sponsor: DOE
- Effect of Alloying and Thermo-Mechanical-Treatment on Anisotropic Creep and Deformation of Ti-alloys
  - Sponsor: NSF
- U.S.-India Cooperative Research: Creep Anisotropy in Titanium-Textural and Microstructural Origin
  - Sponsor: NSF
- A Multiscale Study of Ratcheting Failure Mechanisms in Austenitic and Ferritic Steel Welded Joints
  - Sponsor: NSF

Current Projects - II



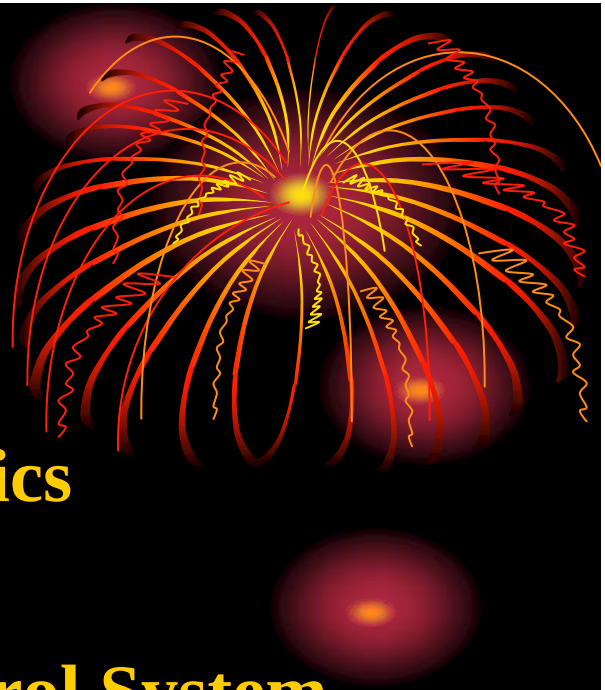
- Effect of Grain Size on the Mechanical Properties of Multi-Phase Alloys
  - Sponsor: NSF
- Deformation Behavior of Nanostructured Materials: A Prerequisite for Design
  - Sponsor: DOE
- Next generation engineered materials for ultra supercritical steam turbines
  - Sponsor: DOE (w/Siemens-Westinghouse)

Research Interests



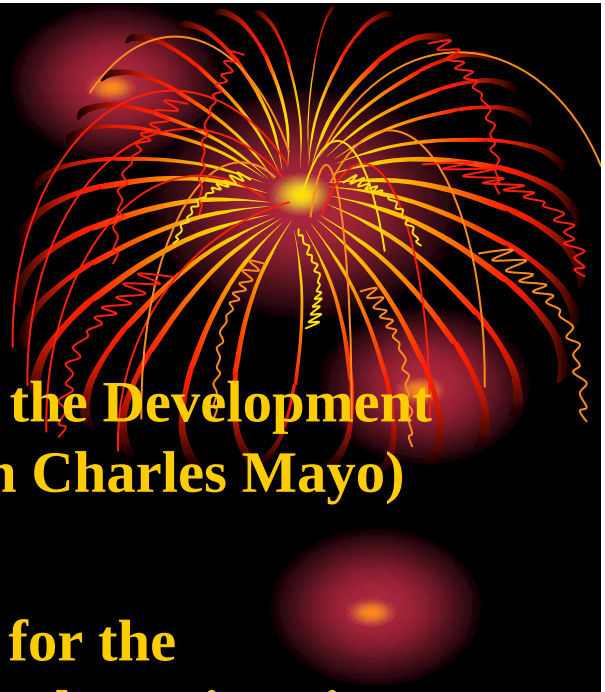
J. Michael Doster
Associate Professor of NE

Overall Interests



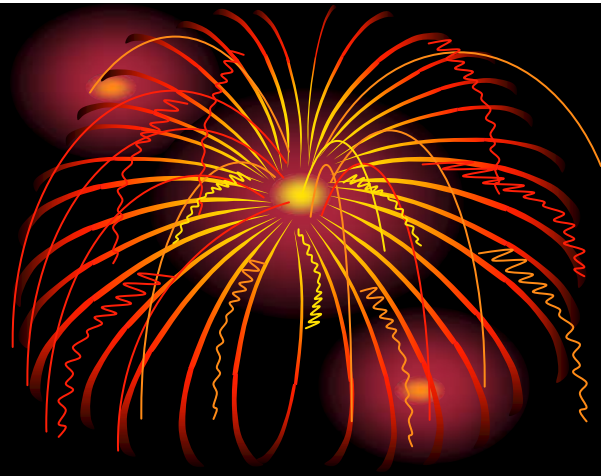
- **Computational Thermal-Hydraulics**
- **Reactor Systems Simulation**
- **Simulation Based Advanced Control System Design**

Specific Interests



- **Applications of High Fidelity Simulation to the Development of Advanced Reactor Control Systems (with Charles Mayo)**
- **Design of High Powered Cyclotron Targets for the production of radiopharmaceuticals (with Duke University Medical Center)**
- **High Powered X-Ray Targets (with Mohamed Bourham)**
- **Understanding and predicting the numerical behavior of computational methods employed in the simulation of nuclear power systems (stability, computational complexity, etc.)**

Current Projects



- **Cyclotron Targetry**
- **Development of methods for advanced full range feedwater control for helical steam generators (IRIS)**
- **Interactive graphical interface for full plant simulator**
- **System dynamics and control for space nuclear power**

Research Interests

Dmitriy Y. Anistratov

April, 2005

Research Areas

- Modeling of interaction of radiation (particles) with matter
  - Neutron transport in nuclear reactors
  - Radiative transfer
  - Charged-particle transport
- Computational physics
- Transport theory
- Numerical analysis

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NEER Research Project (DOE Program)

- *Project: Numerical Methods for Solving Particle Transport Problems on Regular and Unstructured Grids*
- **Fundamental research on computational transport methods**
- **The overall goal is**
  - creating efficient methods for solving multidimensional transport problems
  - development of an unconditionally stable method for solving transport problems on unstructured grids
  - development of new nonlinear methods with advanced properties and adaptive features for regular meshes.
- **Applications**: Radiative transfer problems, reactor physics problems, geophysics problems etc.
- **Graduate students**: Loren Roberts, William Wieselquist

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Computational Methods for Reactor Physics

- *Advanced Computational Tools for Neutronics Calculations for the Next Generation of Reactors*
- **The overall goal of the research**:
  - to develop the next generation of computational methods for analysis of nuclear reactors of the next generation
- **The new methodology for design analysis methods will enable one:**
  - to take accurately into account full-core (global) transport effects
  - to model accurately core/reflector interface
  - to increase significantly the accuracy of cross section collapsing over energy and spatial homogenization
  - to improve the results of calculations of global and local characteristics of neutron distribution in a core of the next generation of reactors
- **The foundation** of this research is the novel methodology that has been developed in the NERI project.

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NERI Research Project (DOE Program)

- **Current reactor analysis methodology**
  - Group data: assembly-level transport calculations with reflective boundary conditions on fine spatial grids with many energy groups.
  - Full-core calculations: the few-group diffusion equations on coarse spatial grids.

- **Weaknesses in current methodology**
  - Diffusion approximation is inaccurate near the interface between unlike assemblies.
  - Reflective boundary conditions in the single assembly calculations.

- **New methodology have been developed that is based on Low-Order Quasidiffusion (LOQD) equations.**
  - Group data: Assembly-level transport calculations with special albedo boundary conditions
  - Full-core calculations: the LOQD equations that can capture the transport effects with an arbitrary degree of accuracy.

- **Collaborative effort**: Project funded by NERI (2000-2003), NC State, Texas A&M, Oregon State, and Studsvik Scandpower, Inc.

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Research Interests

Charles W Mayo
Professor of NE

Overall Interests

- Fission Reactor Engineering Interests: Utilization of instrumentation readings in control systems and diagnostics in support of nuclear power systems.

Specific Interests

- **System diagnostics & signal analysis**
- **Use of computer simulation for research in above areas**
- **System reliability analysis**
- **NDE side of signal analysis**

Current Projects

- Title: **Advanced Control System of Nuclear Power Sources**
  - **Autonomous control**
  - **Automatic startup**
- **Title: Reactor Diagnostics**
  - **Steam generator tube inspection**
  - **Core and other components' vibration patterns**

Research Interests

Paul J. Turinsky

Professor of NE

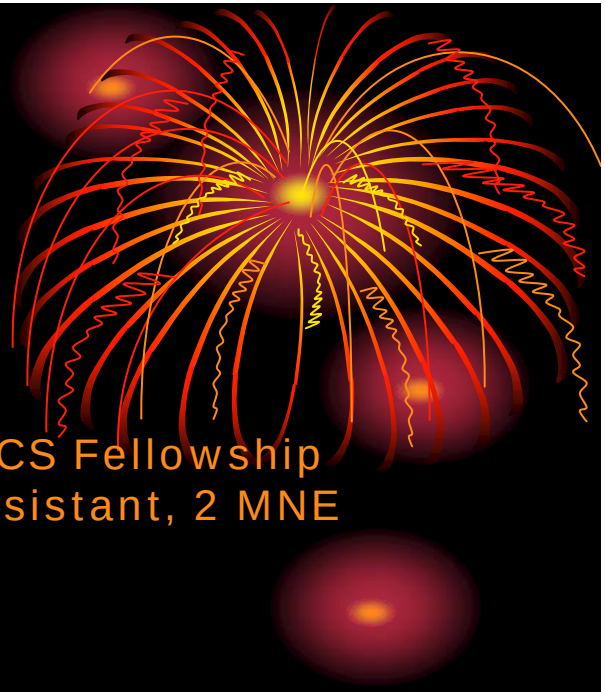
Overall Interests

- Development and automation of computational capabilities to analyze nuclear reactor cores and their associated fuel cycles.

Specific Interests

- Nuclear fuel management optimization of current and advanced core designs and their associated fuel cycles.
- Sensitivity of core, e.g. thermal margins, and fuel cycles, e.g. repository, to input uncertainties, e.g. evaluated nuclear date files.
- Enhancement of core modeling fidelity via
  - Inverse theory applied to create an adaptive core simulation.
  - Enhancement of core simulator modeling capabilities.

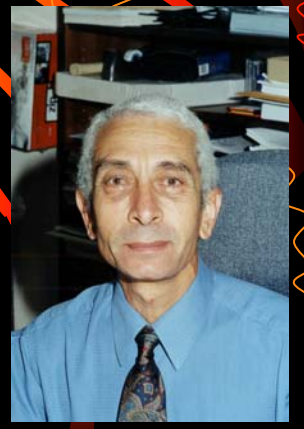
Current Projects



- Nuclear fuel management optimization
  - Sponsor: EPRC, GE/GNF, Duke Power, GAANN CS Fellowship
  - Staffing: 1 Research Associate, 1 Research Assistant, 2 MNE Trainees (new students)
- INL SINEMAN Project
  - Sponsor: INL (likely LDRD)
  - Staffing: 1 Research Assistant (new student)
- Gen IV core (SCWR) design
  - Sponsor: NE
  - Staffing: 1 Research Assistant
- Core modeling improvements (space-time kinetics & space nuclear power)
  - Sponsor: ORNL (hopefully) & NE
  - Staffing: 2 Research Assistants
- Adaptive core simulation
  - Sponsor: GE/GNF, DOE NR Fellowship
  - Staffing: 2 Research Assistants (1 new student)
- Generation of Optimum Many Group X-section Library
  - Sponsor: KAPL (allowing 50% of new hire time)
  - Staffing: 1 Research Assistant

Research Interests

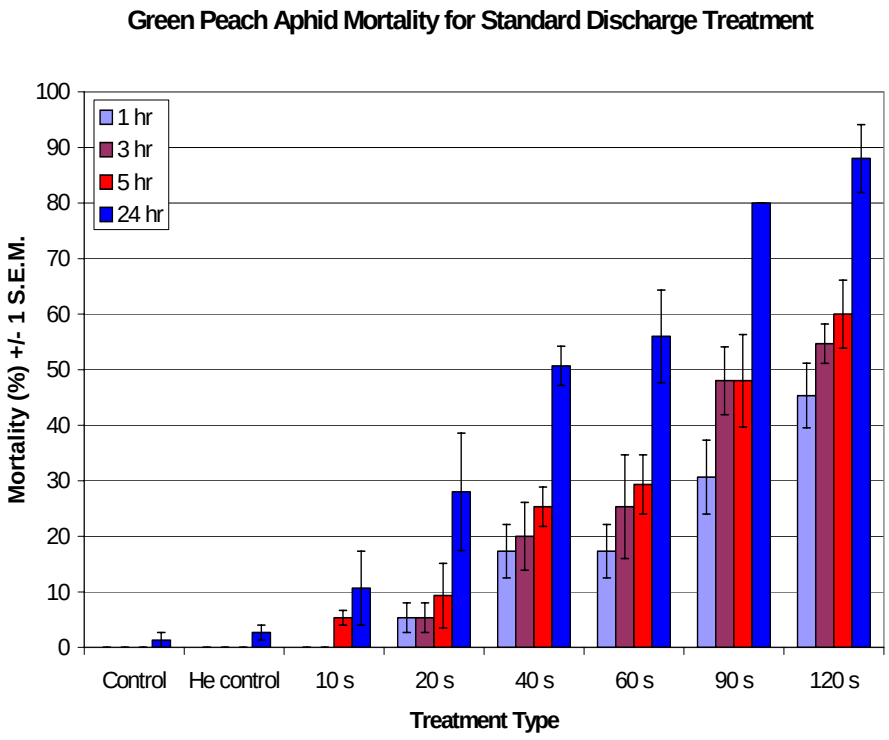
Mohamed Bourham
Professor of NE



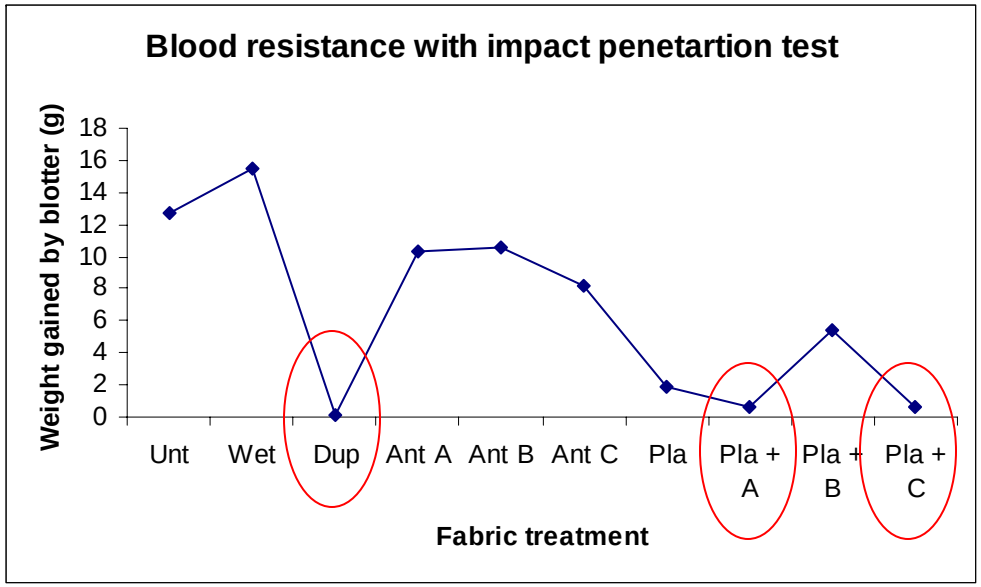
Plasma Engineering

Atmospheric Plasmas and High Density Plasmas

- **Surface sterilization, insect control, surface modifications & functionalization**
- **Plasma-liquid metal interaction for ICF studies**



Mortality of Green Beach Aphids exposed to helium plasma discharge.
Delayed mortality measured up to 24 hours post exposure to plasma



Antimicrobial fabric finishes showing plasma treated versus commercial Dupont product

R.K. Virk and G.N. Ramaswamy (Kansas State Univ.) and B.L. Bures and M.A. Bourham (NCSU), J. Textile Research, Vol.47 (12) Dec. 2004.

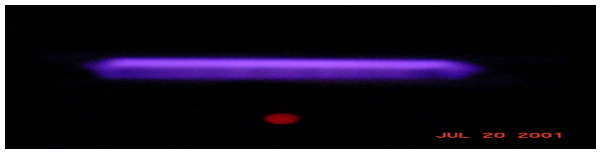
NC STATE UNIVERSITY

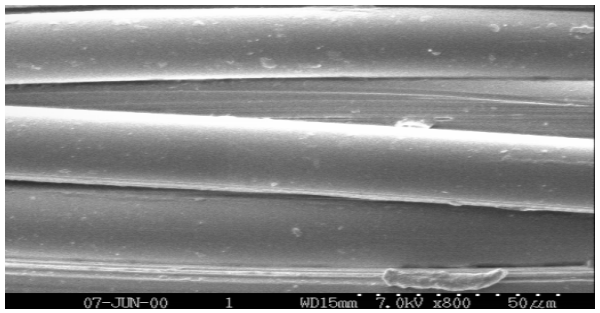
Department of Nuclear Engineering

Plasma Engineering
Application To Textiles

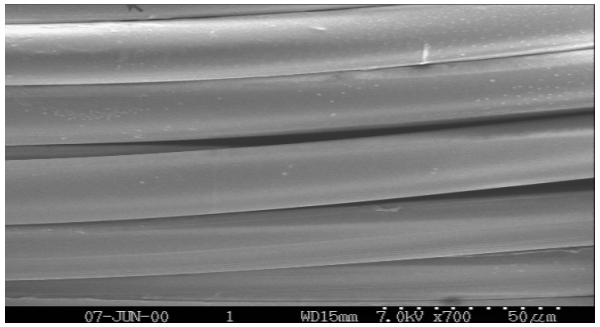
Purpose: Produce enhanced fabric properties via surface modification

Advantages: On-line treatment, continuous process, energy efficient, non-chemical and reduced waste





Untreated Nylon 6,6

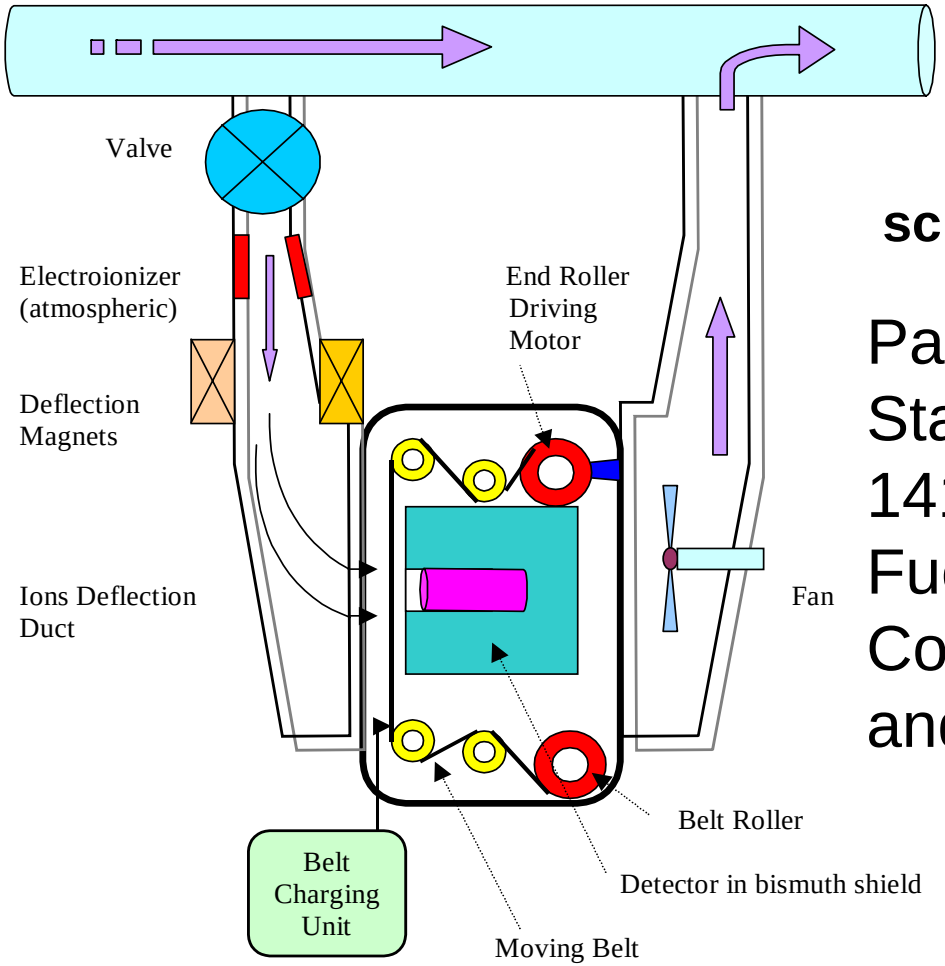


Treated Nylon 6,6

Reactors and Radiation Detection

On-Line Fuel Failure Monitor for Very High Temperature Gas Cooled Reactors. DOE NERI Award with Ayman Hawari 2005-2008)

Hazard Detection and Communication Under Nuclear Terrorist Attacks (NSF – Under Review)



schematic of the failed fuel monitor

Patent disclosure, North Carolina State University, File Number 04 - 141, June 30, 2004, “On-Line Fuel Failure Monitor for Gas-Cooled Reactors”, Ayman Hawari and Mohamed Bourham.

Research Interests

Ayman Hawari
Associate Professor of NE
Director-Nuclear Reactor Program

Gen. IV Reactors Research

- Neutronics-Materials interface
  - Development and validation of thermal neutron scattering laws

    (collaboration with ORNL, NERI 2001-2005)
    - Graphite – main focus
      - Experiment set up at ORELA and will be executed if ORELA comes back on-line
  - Application of a better theoretical treatment of thermal neutron scattering
  - Utilization of Ab Initio condensed matter physics methods for the generation of the required fundamental data
  - Exploration of the applicability of molecular dynamics models to understand the impact of radiation damage on neutronics

    (INL subcontract 2005)

AFCI Research

- Development of passive and active fuel assay methods
  - On-line burnup monitoring for the PBR (NERI 2000-2003)
    - Estimation of the burnup dependent gamma-ray emission spectrum of fuel pebble's
    - Simulation of the detector response
    - Defining proper burnup indicators
  - On-line fuel failure detection for the VHTR (NERI 2005-2008 w/ M. Bourham)
    - Use a passive gamma-ray spectrometry approach
    - Integrate release-to-birth models in estimation of the gamma-ray emission spectra
    - Develop instrumentation and methods for extracting failure mode information from gamma-ray spectra

Radiation Detection

- Basic gamma-ray spectrometry
  - Development of improved methods for HPGe detector calibration

    (LANL subcontract 2002-2005)
- Neutron detection
  - MC Design and testing of Gaseous Electron Multiplier (GEM) detectors for utilization in neutron scattering applications

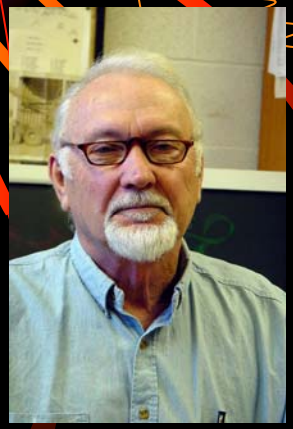
    (Industrial subcontract 2005-2006)

Research Reactor Applications

- Development of unique fundamental and applied capabilities at the NCSU PULSTAR reactor
  (INIE and NSF funding 2003-2008)
  - Neutron Imaging
    (Collaboration with NIST, INIE funding)
  - Intense positron beam
    (Collaboration with U. Michigan physics and ORNL
    INIE funding, NSF proposal pending)
  - Powder neutron diffraction
    (led by R. Berliner, INIE funding)
  - Intense Ultra-Cold Neutron source
    (Collaboration with NCSU physics, INIE & NSF funding)

Research Interests

Robin Gardner
Professor of NE



Overall Interests

- Industrial (and Medical) Radiation and Radioisotope Measurement Applications

RESEARCH AREAS

- Radioisotope Tracer Applications – Single Radioactive Particle Tracking (RPT) for PBR's
- Radiation Gauging Applications – Oil Well Logging Devices and Al Thickness Gauging
- Radiation Analyzer Applications – Prompt Gamma-Ray Neutron Activation Analysis (PGNAA) and Energy-Dispersive X-Ray Fluorescence (EDXRF)
- Imaging - Prompt Gamma-Ray Imaging (PGI) of Mice
- Monte Carlo Simulation of All
- Radiation Detection – Detector Response Functions (DRF's) and Pulse Pile-Up Modeling

NC STATE UNIVERSITY

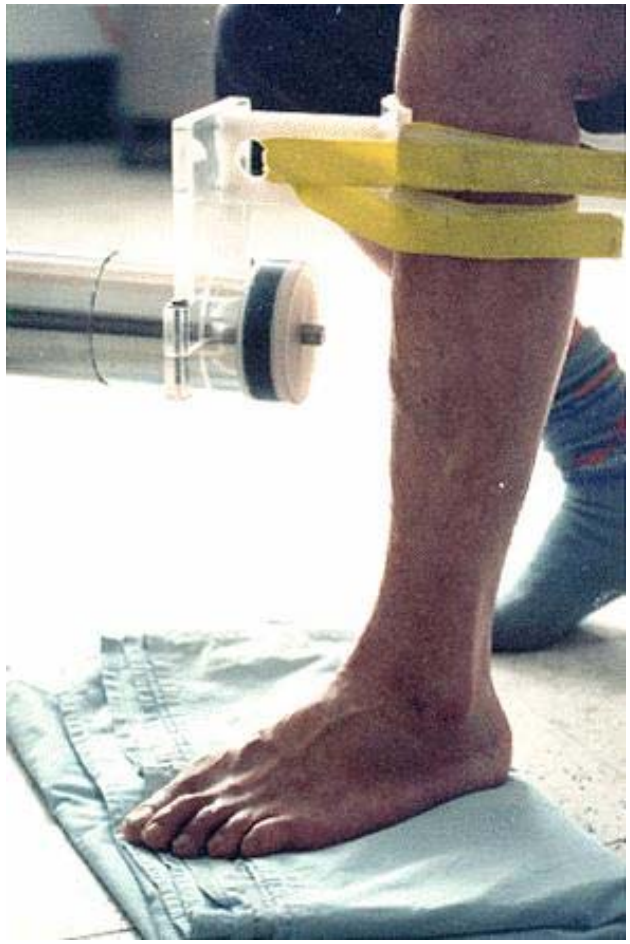
Department of Nuclear Engineering

Medical Physics

Application to *In Vivo* XRF Measurement of Lead in Bone

Purpose: Measure lead accumulation in the body by *in vivo* X-Ray Florescence (XRF) of the tibia (leg bone)

Advantages: Radiation dose is less than a dental X-ray, and children & susceptible workers are easily monitored since non-invasive procedure



Research Activities and Opportunities

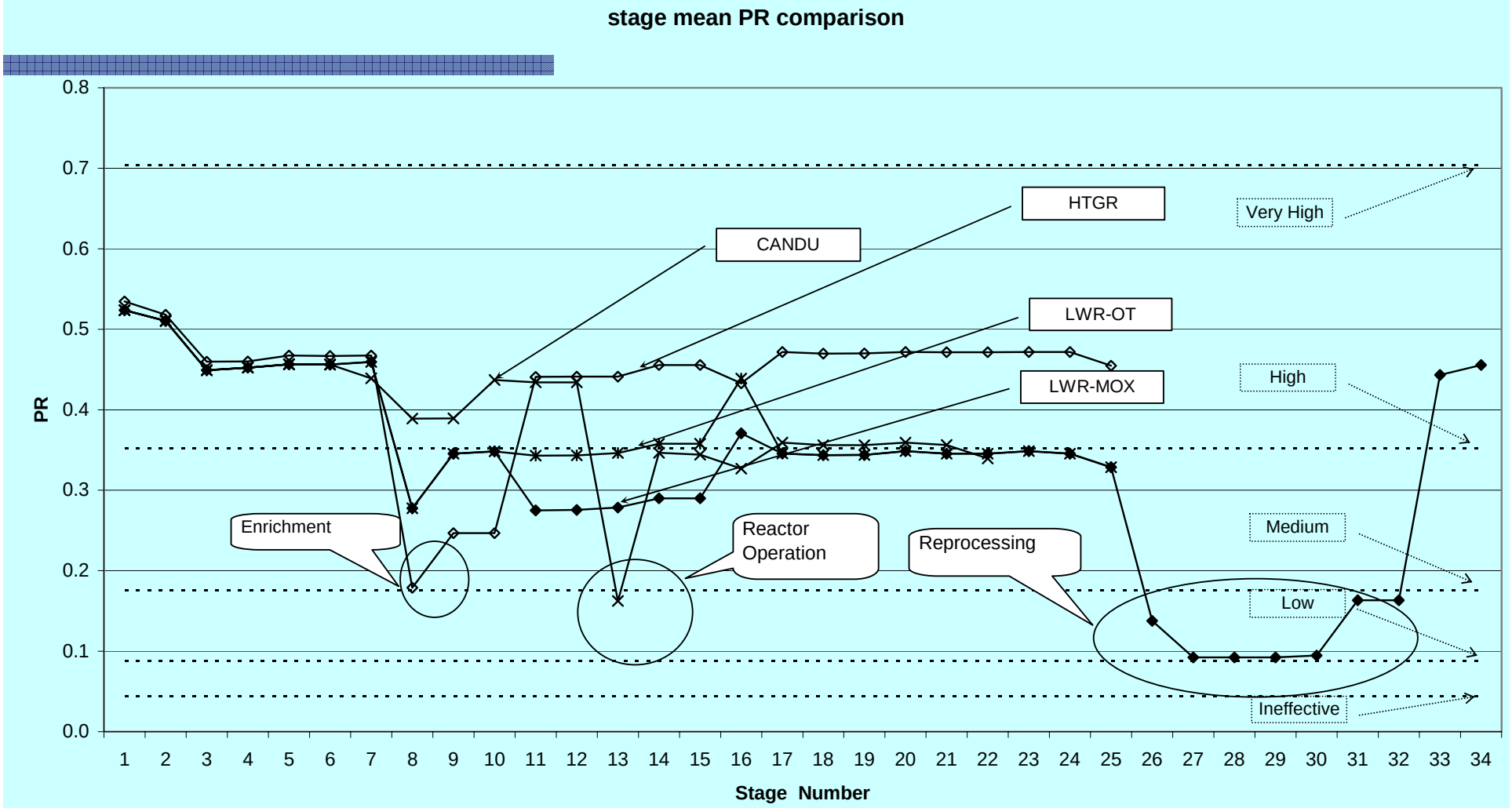
Man-Sung Yim

Department of Nuclear Engineering
North Carolina State University

Advanced Fuel Cycle Analysis

- Proliferation resistance assessment method development
- An integrated repository impact assessment model development
- Nuclear waste transmutation analysis
- Nonproliferation policy studies

Comparisons of Proliferation Resistance (based on stage mean values) using a Fuzzy-Logic Based Barrier Model



Nuclear Waste Management

- Investigation of multilayer coating application to HLW packages for performance enhancement
  - Multiple layers of coating (TiN/ZrO_2, TiN/Ti/TiN, etc.) have been found to be effective for:
    - Adhesion to substrate
    - Additional corrosion protection in Yucca Mountain simulated water
- Investigation of optimum cask loading for spent nuclear fuel transportation and related risk analysis