The Value and Impact of the NRC Faculty Development Program at Illinois

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NRC Regulatory Information Conference
10-12 March 2020
Nuclear Power in Illinois

- 11 operating units at 6 sites
- 11,590 MWe Capacity or roughly 50% of electricity generation in Illinois
- One Nuclear Engineering Degree Program – NPRE at UIUC
- Agreement State
NPRE Structure

Nuclear Power Systems, Safety & Environment

Nuclear Fusion & Plasma Applications

Radiological Engineering

Cross-cutting
- Materials
- Radiation Measurement and Applications
- Thermal Science & Heat Transfer
- Risk and Reliability
- Controls and Instrumentation

ENGINEERING AT ILLINOIS
NP RE Structure

- Nuclear Power Systems, Safety & Environment
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- Cross-cutting
  - Materials
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ENGINEERING AT ILLINOIS
Faculty Fall 2019
NPRE Illinois Faculty Numbers

NPRE Faculty Numbers

- Total
- Assist
- Assoc
- Full

Year: 2010 to 2020

Engineering at Illinois
Innovative Research
Analysis of Reactor Transients and Stability (ARTS)

Research Interests
• Reactor Physics and Thermal-Hydraulics
• Uncertainty Analysis, Bayesian Methods
• Multi-Physics Coupling Methods
• Reactor Design and Safety Analysis
• Numerical Analysis, Computational Methods

Current Projects
• Molten Salt Reactor analysis: load-following capability, kinetics, fuel cycle, fission product removal, material inventory
• Uncertainty quantification of two-phase flow physical models parameters: Bayesian modeling, surrogate models, model inversion
• Validation of RELAP-7 for forced convection and natural circulation reactor flows: calibration, validation, uncertainty and sensitivity analysis for predictive models
• High-order methods for two-phase flow: stable and convergent approximate Riemann solver for two-phase two-fluid model

Interest areas for collaboration/future work
Reactor physics and reactor thermal-hydraulics, Multi-scale multi-physics coupling methods, Deterministic reactor safety methods, Numerical analysis, BWR stability, Uncertainty quantification

Tomasz Kozlowski
Innovative Research
Nuclear Reactor Thermal Hydraulics

Research Interests
- Experimental data and modeling of two-phase flow and heat transfer
- Validation of system analysis and computational fluid dynamics codes
- Infrastructure for TH research on molten salt

Outcomes over award period
- 21 high impact journal articles
- 18 conference papers

Select papers
Innovative Research
Advanced Reactors and Fuel Cycles

Research Interests
We design software and conduct massive-scale simulations to understand and improve the safety and sustainability of nuclear energy.

- Advanced nuclear reactor safety (PyRK, PyNE)
- Nuclear fuel cycle simulation (Cyclus, SaltProc)
- Coupled multi-physics for circulating fuel reactors (Moltres)
- Isotope identification with neural networks (annsa)

Outcomes over award period
- 14 journal articles, 9 refereed conference papers
- Over 700 citations since joining NPRE

Campus Affiliations
- Blue Waters Assistant Professor
- National Center for Supercomputing Applications
- Computational Science and Engineering

Select papers
Innovative Research
Molecules, Materials, and Machines

Research Interests

Centering around non-equilibrium physics, the research in YZ’s group can be summarized in three words: **Molecules, Materials, and Machines.** Their vision is to first understand the emergent laws of matter at the molecular and electronic level, then create materials with desired properties, and ultimately build intelligent machines using these tailored materials.

- **Molecules & Materials**
  - [Long Timescale Phenomena, Rare Events]
  - Non-equilibrium Physics and Accelerated Molecular Simulations
  - Physics and Chemistry of Liquids and Molecular Fluid Mechanics especially under interfacial/non-equilibrium/extreme conditions

- **Machines**
  - Soft Robotics and Human-Compatible Machines, Control, AI
  - Bio-inspired Design (Vasoconstruction-like Flow Regulator)
  - 3D Printed Microfluidics

- **Novel Materials**
  - Self-healing Ionic Glass/Rubber
  - Confined Proteins
  - Molecular Cage Porous Liquid
  - Unreheated Modular Soft Arm
  - Self-healing, Intelligent & Continuous Control (Patent Pending)

- Publications >50
- Citations >1500
- H-index = 19
- Annual research expenditure >$800k
- Invited talks > 50
- ANS Landis Award
- ACS PRF Doctoral New Investigator Award
- Associate Editor, *Science and Technology of Advanced Materials* (IF = 4.787)
- Group Leader of Computational Molecular Science at Beckman Institute
Innovative Research
Radiation Detection and Applications

Research Interests

- New detection systems for neutron spectroscopy
  - Deuterated stilbene with superior pulse shape discrimination and fast-neutron spectroscopy capabilities
  - Multisphere spectrometers based on elpasolite scintillators capable of operating under high fluence rates
- Inference-based algorithms for security, safeguards, and nonproliferation
  - General-purpose C# platform for fast processing of radiation detection data [1] – available at https://gitlab.engr.illinois.edu/nml
  - Bayesian unfolding algorithms for neutron spectroscopy and radionuclide unmixing [2]
  - Machine-learning imaging for early detection of spent fuel diversion applied to the IAEA Passive Gamma Emission Tomography system

Select papers


Angela Di Fulvio

Custom-grown deuterated stilbene crystal, in collaboration with Lawrence Livermore and Oak Ridge National Labs and University of Michigan Physics Dept.

NPRI research assistant using the developed multisphere spectrometer at Idaho National Laboratory.
Innovative Research
Risk & Reliability

Probabilistic Risk Assessment (PRA)

Area (I) Spatiotemporal coupling of physical failure mechanisms with human/social performance and generating Integrated PRA (I-PRA)

Area (II) Incorporating big data analytics into PRA

Area (III) Integrating safety risk and financial risk


Zahra Mohaghegh

19 High-Impact Journal Papers
43 Conference Papers
830 Citations - Google Scholar

RESEARCH & DEVELOPMENT TOPICS

- Generic Safety Issue 191 (GSI-191)
- Fire PRA
- Common Cause Failure Analysis
- Passive Component Reliability Analysis
- Level 3 PRA
- Diverse & Flexible Coping Strategy (FLEX) Analysis

- Data-Theoretic Methodology for Human & Organizational Factors in PRA
- Integrated Enterprise Risk Management (I-ERM)
- Monetary Value of Risk-Informed Applications
NRC Faculty National and International Awards

1. Clair Sullivan, ANS Oestmann Achievement Award – 2015
2. Tomasz Kozlowski, ANS Landis Young Member Award – 2015
3. Zahra Mohaghegh, ANS Oestmann Achievement Award – 2016
4. Katy Huff, ANS Young Member Excellence Award - 2016
5. Yang Zhang, ANS Landis Young Member Award – 2017
6. Katy Huff, ANS Oestmann Achievement Award – 2017
7. Caleb Brooks, AESJ Society-wide Shorei-sho Award - 2017
8. Ling Jian Meng – ANS-IRD Radiation Science and Technology Award - 2018
9. Caleb Brooks AESJ Thermal Hydraulics Division Shorei-sho Award - 2018
10. Majdi Radaideh, ANS Mark Mills Award – 2019 (PhD Student of Tomasz Kozlowski)
NRC Scholarships & Fellowships

NRC Scholarship Program
- 98 Undergraduates in Nuclear Engineering
- Nuclear Power & Radiological Engineering
- Many Have Gone to Grad School – Top Students! (big change in the last 10 or 15 years)
- Others Have Gone to Nuclear Industry – Exelon and others

NRC Fellowship Program
- Attract Highly Qualified Domestic Grad Students
- 19 Grad Students
- 9 Still in Grad School working on their PhDs
- 10 National Labs (ANL, LANL, ORNL), TerraPower/Exelon, Academia, Westinghouse/NEI, Kairos
Summary & Comments

Major New Strengths and Accomplishments
- Reactor Analysis
- Thermal-Hydraulics
- Fuel Cycle Analysis
- Nuclear Materials and Materials Science
- Radiation Detection and Applications
- Risk, Reliability and Safety Analysis
- Great Students!

Value of NRC Faculty Development Awards
- Attract High Quality Faculty and Strengthen Faculty Diversity
- Provides Competitive Advantage with Industry, National Labs, and Other Engineering Disciplines
- Faculty Start-up Costs are Significant
- Heavy Demands on New Faculty Member for a Fast, Strong Start to meet Research, Teaching and Promotion Expectations
Thank you
Questions and Comments