NC State University Overview

Yousry Y. Azmy
Distinguished Professor, Nuclear Engineering
NC State University
**NEUP Projects**

- **IRP:** *Development and Application of a Data-Driven Methodology for Validation of Risk-Informed Safety Margin Characterization Models*
  - NCSU: Nam Dinh (PI), Igor Bolotnov, John Baugh, Abhinav Gupta, Maria Avramova
  - INL: Cristian Rabiti, Robert Youngblood, Steven Prescott

- **R&D:** *Microstructure Experiments-Enabled MARMOT Simulations of SiC/SiC-based Accident Tolerant Nuclear Fuel System*
  - NCSU: Jacob Eapen (PI)
  - INL: Daniel Schwen

- **R&D:** *Three-Dimensional Fuel Pin Model Validation by Prediction of Hydrogen Distribution in Cladding and Comparison with Experiment*
  - NCSU: Maria Avramova (PI)
  - INL: Richard Williamson
Other Research Projects & Proposals

- **Numerical Simulation of High Wind Impact on Nuclear Energy Facilities**
  - INL: Steven Prescott (PI)
  - NCSU: Nam Dinh (NE) & Abhinav Gupta (CCEE)

- **NCSU Participation in IAEA Coordinated Research Program on HTGR Uncertainty Analysis in Modeling**
  - NCSU: Kostadin Ivanov (PI)
  - INL: Gerhard Strydom

- Proposal to NSF to further develop Zapdos application for plasma simulation in MOOSE, ~$250K:
  - Academic Collaborators: Steve Shannon (PI, NCSU), Davide Cirreli (UIUC), Tom Kirchner (APS)
  - Lab Collaborators: Rich Martineu (INL), David Green (ORNL)
  - Status: Recommended for funding
NUC – LDRD Projects

• Project – *Nuclear Hybrid Energy Systems*:
  – INL Lead: Shannon Bragg-Sitton
  – NCSU Collaborators: Steve Terry (MAE), Mike Doster (NE)
  – Other NUC Collaborators: Carol Smidts (TOSU), Qiao Wu (OSU)
  – Status: Ending
  – Success: This year’s CINR includes scope NE-2: *Hybrid Energy Systems Design and Modeling*

• Project – *Coarse-grain Computational Fluid Dynamics*:
  – INL Lead: Robert Youngblood
  – NCSU Collaborators: Nam Dinh & Igor Bolotnov(NE)
  – Status: Continuing as regular LDRD project with NUC partial support
Key Publications & Presentations


Key Publications & Presentations (cont’d)

• Odeniyi, A and Terry, SD, "Hybridization and Optimization of Gas Turbines for Compressed Air Energy Storage Systems", *IETC Conference*, New Orleans LA, June 2017


Presentations

Accepted for Publication/Presentation


- Misenheimer, CT and Terry, SD, “The Development of a Dynamic Single Effect, Lithium Bromide Absorption Chiller Model with Enhanced Generator Fidelity,” Energy Conversion & Management (in final review)
Outcomes: INL-Supported Students Progress

- Tucker Daniels (Terry) – Earned MS ME August 2017
- Payel Chatterjee (Gupta; NUC-intern, Sp 2016) – Earned PhD Fall 2016
- Corey Misenheimer (Terry) – Earned PhD in ME August 2017
- Daniel Mikkelson (Doster; LDRD-supported) – Expected PhD: May 2019
- Konor Frick (Doster; NEUP Fellow) – Expected PhD: May 2018
- Botros Hanna (Bolotnov & Dinh) – Expected PhD: May 2018
- Linyu Lin (Dinh) – Expected PhD: September 2018
- Han Bao (Dinh) – Expected PhD: March 2019
Outcomes: INL Graduate Fellowship Winners

- Six applications from NCSU, 2 awarded

- Kono Frick (NCSU Advisor: Mike Doster, NE):
  - INL Mentor: Shannon Bragg-Sitton
  - Start date: Dec 2017
  - Project: Development and simulation of a coupled Thermal Energy Storage System for deployment in nuclear hybrid energy systems

- Casey Icenhour (NCSU Advisor: Steve Shannon, NE):
  - INL Mentor: Rich Martineau
  - Start date: Dec 2017
  - Project: Expansion of MOOSE capability to address a broader class of problems in nuclear science and engineering using vector finite elements
Other Engagements with INL

- 2017 Summer internships at INL: **16 students**
- Kelly Beierschmitt’s visit to NCSU, May 3-4, 2017
  - Mark Peters cancelled due to Secretary Perry’s INL visit
- Shannon Bragg-Sitton (INL) Adjunct Prof of Nuclear Eng:
  - Serve on PhD Comms of Daniel Mikkelson & Konor Frick (Doster)
- Joint Faculty Appointment with INL: Dr. John Gilligan, NEUP Director
- Co-proposed *Big Idea* from last NUC Quarterly Meeting coincided with INL’s VFNS push:
  - Continued supporting VFNS planning stage throughout year
Multi-Physics Model Validation Workshop

- June 27-29, 2017, organized on NCSU Campus by:
  - Nam Dinh, Maria Avramova, & Kostadin Ivanov (NCSU)
  - Hans Gougar (INL)
- Co-sponsors with NUC:
  - OECD/NEA’s Expert Group on Multi-Physics Experiments, Benchmarking and Validation
  - Nuclear Energy Knowledge and Validation Center (NEKVAC)
- Objective: Identify emerging needs, technical challenges/opportunities in validation & UQ for nuclear systems multi-physics models
- Outcomes: Captured state-of-the-art in multi-physics M&S tools
  - 63 participants: academia, industry, regulators, national & naval labs, research institutions, consultants; from different countries
  - 6 panel discussions + poster session
  - 36 presentations in 6 focused sessions
Workshop Outcomes

• Identified trends in multi-physics modeling and simulation
• Addressed V&V and UQ trends/issues for traditional/novel multi-physics tools
• Summarized emerging R&D needs for V&V
• Discussed emerging requirements for multi-physics tools
• Developed strategy for validation data management
• Identified collaboration opportunities in multi-physics model validation

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<thead>
<tr>
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<th>Validation process</th>
<th>Abundance of Application</th>
<th>Abundance of IEs</th>
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Workshop – Action Items & Future Activities

- Archive Workshop materials + Summary in NE-KAMS database → follow on activities

- Seek future funding – Compose & submit to INL & DOE-NE:
  - White Paper on emerging needs, technical challenges & opportunities in validation & UQ for nuclear systems multi-physics models
  - Proposal to better coordinate different multi-physics model validation activities among domestic/international organizations:
    - IAEA CRPs
    - NEA/OECD expert groups

- Support joint (inter-organizational/national) MS and PhD research & theses in the area of multi-physics model validation

- Conduct annual workshops on multi-physics validation:
  - Share/inform/educate modern code developers & experimenters on state-of-the-art in validation of advanced complex simulations
Plans for FY2018

- Support INL’s efforts on VFNS
- Partial support from NUC $ for continuing LDRD project on Coarse-grain Computational Fluid Dynamics
  - This will consume roughly half NCSU’s NUC $
- Facilitate more engagement between NCSU faculty & INL staff:
  - Support multi-day visits by faculty to INL potential collaborators
    - This will likely consume a third of NCSU’s NUC $
    - Follow up on action items from Kelly’s visit to NCSU
- Workshop Series on Severe Accident Analysis:
  - 2014 & 2016 Workshops focused on LWR & ALWR
  - 2018 focus on safety design & safety analysis for advanced non-LWR plants?
    - Relevance to VFNS + growing needs: industry, DOE & NRC
- Senior design project on HTGR reactor design – Maria Avramova:
  - INL: Cristian Rabiti’s group
Extra Slides
DELETE
Summary of Other Activities

- List other activities that were funded by NUC in FY2017 (not LDRD), including:
  - Workshops (title and # participants)
  - Trainings (title and # participants)
  - Trips to INL (when, who went, brief purpose).
  - Students funded (name and degree pursuing)
  - Publications and White Papers
  - Invited talks
  - Patents and/or invention disclosures
Yes, I would like to continue the series on "Severe Accident Analysis: Emerging Issues and Research Directions" that attracted a broad interest in 2014 and 2016. The focus of these previous workshops was on LWR and ALWR. This time, I suggest to focus on safety design and safety analysis for advanced non-LWR plants. This theme builds on industry's, DOE's and NRC's growing interest in these advanced designs. This meeting may help bring awareness of issues in safety and licensing of advanced reactors and create opportunities for university research and collaboration. In addition, this topical meeting will support a new initiative of DOE on fast reactor-based VFNS.

I will check interest of potential participants and suggest a specific title (if we want to narrow the scope) when we announce the workshop).

Please let me know if you have other suggestions.

I also wonder if INL has any input on the topic and agenda (they were hands-off previously).
The Multi-Physics Model Validation Workshop took place on June 27-29, 2017 at NCSU (Organizers: Nam Dinh, Maria Avramova, and Kostadin Ivanov from NCSU; Project leader: Hans Gougar – INL).

The workshop’s objective was to bring together researchers from academia, industry and government to discuss emerging needs, technical challenges, and opportunities for R&D and collaboration on validation and uncertainty quantification of multi-physics models in nuclear reactor and nuclear energy applications.

The workshop was organized by the NCSU’s Department of Nuclear Engineering in cooperation of OECD/NEA Expert Group on Multi-Physics Experiments, Benchmarking and Validation (EGMPEBV), with support from the Idaho National Laboratory through its National University Consortium (INL-NUC) program and Nuclear Energy Knowledge and Validation Center (NEKVAC) program.

This workshop provided participants with understanding and knowledge of state-of-the-art concepts, principles, procedures, and challenges for validation of traditional, and novel multi-physics modeling and simulation tools.

In total 63 participants from industry, regulatory agencies, national labs, naval labs, research institutions, consulting companies, and academia from different countries.

6 focused sessions with 36 presentations, and 6 panel discussions and 9 posters in a poster session. The workshop materials and presentations can be downloaded at:

https://www.ne.ncsu.edu/outreach-engagement/workshops/multi-physics-model-validation-workshop/
Multi-Physics Model Validation Workshop at NCSU

Outcomes of the Workshop

- Trends in multi-physics modeling and simulation have been identified;
- Verification & validation and uncertainty quantification trends and issues for multi-physics tools (both traditional and novel) have been addressed;
- Emerging research & development needs for V&V have been summarized;
- Emerging requirements for multi-physics tools have been discussed;
- The strategy for validation data management has been developed;
- Collaboration opportunities in multi-physics model validation have been identified.

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![Diagram showing the degree of coupling and applications abundance](attachment:diagram.png)
Multi-Physics Model Validation Workshop at NCSU
Action items & future activities

○ White Paper will be prepared based on technical presentations and discussions at the workshop focused on lessons learned about emerging needs, technical challenges and opportunities for R&D and collaboration in validation and uncertainty quantification of multi-physics models in nuclear reactor and nuclear energy applications.

○ Workshop materials, and summary will be submitted to the INL (and will be archived on the NE-KAMS database) and may lead to follow on activities.

○ Proposal will be prepared for strengthening the coordination of different activities in multi-physics model validation – within organizations, within national multi-organizational joint activities and programs; and within international programs such as IAEA CRPs and NEA/OECD expert groups and benchmarks.

○ Support joint MS and PhD research and theses in the area of multi-physics model validation;

○ Conduct annual workshops on multi-physics validation that will share/inform/educate modern code developers and experimenters in state-of-the-art on how to validate advanced complex simulations.