



Department of Nuclear Engineering

# ANS SR Virtual STEM College Night North Carolina State University

(aka, Raleigh may be great as is NC State but I am here to tell you about the Nuclear Engineering Department)

## Nuclear Engineering Department (NED) at NCSU

- 1<sup>st</sup> Undergraduate and Graduate Nuclear Engineering Degree Programs in the world, Fall 1950
- In 2020 we are celebrating 70<sup>th</sup> anniversary of our academic programs
- 1<sup>st</sup> University to design, build and operate a nongovernmental nuclear reactor
- Since then four research reactors have been built and operated
- The current PULSTAR reactor become critical in 1972 - 1-MWth power (2-MWth upgrade pending licensing with US NRC – expected in 2020)
- Currently the NC State University (NCSU) Nuclear Engineering Department (NED) is the largest standalone Nuclear Engineering department with research reactor in the Southeast











## **State of NCSU NED**



- In the last years, the NCSU NED has been on a trajectory of growth and diversification
- Expenditures (2015-2019) = \$ 81 M
- Tenure/Tenure-Track faculty increase (2015 2019) 37%
- PhD enrollment increase (2015 2019) 52 %
- Improved cooperation with national labs, industry and governmental/international agencies
- Improved national and international visibility, rankings, credibility and recognition
- Developing next 10-year vision and 5-year strategic plan
- Transitioning from a premier to a leading Nuclear Engineering Department







# NCSU NED

- 22 tenured/tenure-track, 3 research & 1 teaching faculty
- 4 Distinguished & Endowed Professorships, 2 Distinguished Alumni Graduate Professors & 1 Distinguished Alumni Undergraduate Professor
- 2 Joint Faculty Appointments (JFAs) with ORNL, 5 JFAs with INL, and 1 JFA with SRNL
- In Fall of 2020 129 (90 PhD) graduate & 107 undergraduate students







## **NCSU NED**

### **Major Research Areas**

- Reactor Systems Engineering
- Radiation Interactions & Detection
- Plasma Science & Engineering
- Nuclear Fuel & Materials

### **Crosscutting Research Areas**

- Nuclear Reactor Program
- Nuclear Security & Nonproliferation
- Nuclear Waste Management
- Modeling & Simulation
- Health Physics

### **Research Facilities, Consortia & Centers**

- Nuclear Reactor Program Center
- Center for Low Temperature Plasma Interactions with Complex Interfaces
- Center for Critical Infrastructure Protection & Facility Decommissioning (CNEFS)
- Consortium for Nuclear Power (CNP)
- INL National University Consortium (NUC)











## **State of NCSU NED**



Department of Nuclear Engineering

- NC State's Nuclear Engineering programs are recognized and respected nationally and internationally
- NC State's Nuclear Engineering Graduate Program sustained the rank #3 by US News & World Report in 2020
- NC State's Online Master of Nuclear Engineering sustained rank #1 by Best College Reviews in 2020
- Special Faculty Appointments

Gilligan: Director, US-DOE's Nuclear Energy University Program (NEUP)

Turinsky: Presidential appointment to the Nuclear Waste Technical Review Board (NWTRB)

<u>Ivanov</u>: Member of BEA INL Board of Managers (BOM) and Science and Technology (S&T) Committee; Chair of Nuclear Engineering Department Heads Organization (NEDHO); and member of Nuclear Energy Institute (NEI) Advisory Board

### o International Programs Leadership

Avramova & Ivanov: Coordinators of OECD/NEA LWR UAM benchmark activities

Hou & Ivanov: Coordinators of OECD/NEA C5G7-TD benchmark activities

Avramova: Co-Chair On Expert Group on Core Thermal-Hydraulics at NEA/OECD

Ivanov: IAEA CRP on HTGR UAM Coordinator

Avramova: CTF Users Group Coordinator

(60 global organizations from industry, research institutes, regulators & academia)

Ivanov: Member of the Nuclear Science Committee (NSC) of the Nuclear Energy Agency (NEA)-OECD and Chair of Working Party on Scientific Issues of Reactor Systems (WPRS) at NSC, NEA-OECD

# **State of NCSU NED**

- 5 new tenure-track faculty hires in 2019
- Partner in US DOE-funded Center for Low Temperature Plasma Interactions with Complex Interfaces
- Constructing: Fission Gas Loop, Hot Cell Facility, and Ultra-Cold Neutron Source
- Developing:
  - Undergraduate concentrations in Plasma Science and Engineering, and Nuclear Materials





- Graduate Certificates in Health Physics and Nuclear Reactor Engineering,
- Graduate concentrations in Plasma Science and Engineering and Nuclear Materials
- Joint Distance Education (DE) MNE Program with BRES and DE component of NE PhD Program
- The Nuclear Engineering Department is being united in the Burlington Labs Bldg. in the fall of 2020, which will become a premier nuclear engineering building hosting all of the nuclear engineering facilities, offices, spaces and conference rooms.



## Nuclear Reactor Program UNC Board of Governors Center

# Major Materials Examination and Irradiation Capabilities

- Neutron powder diffractometer
- Neutron imaging (real time radiography and tomography)
- Intense positron beam (only one in the US)
- Fuel testing & fission gas release loop (beam port testing) (new)
- Ultra cold neutron source (fundamental science, ex-core testing)
- Neutron activation analysis elemental forensics facilities
- Hot cell facility (new)
- In-pool irradiation testing facilities
  - Facilities offer filtered thermal and meV monochromatic neutron beams, and monoenergetic keV positron beams

## Currently operating to support critical government projects





- Internet Reactor Lab (top)
- PULSTAR bay (left)
- Beam facilities (Bottom)



### National & International Partnerships

- Partner in the DOE/INL NSUF
  - Experiments conducted at PULSTAR
- Partner with DOE NE (and Labs) to develop international educational programs
  - Internet Reactor Laboratory
- Partner in NSF RTNN (Research Triangle Nanotechnology Network)
- Member of International Group of Research Reactors
- Member of NNSA Nuclear Data Advisory Group
- Lead of OECD/NEA WPEC SG48 nuclear data group (new)
- Partner with IAEA in various activities
  - Host of IAEA Fellows
- Organizer of international meetings
  - IGORR 2019, PHYSOR 2020, TRTR 2021, ...



### CASL and NEAMS scopes have been merged into a new DOE Joint Modeling and Simulation Program:

- Scope includes all reactor types (LWR, Fast Reactors, Gas-Cooled, Molten Salt, etc.)
- Focus directly aligns with RDFMG and Advanced Reactor Research in the Department
- Post-CASL Funding:

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- Scott Palmtag Chief Technologist Position of CASL through June 2020
- Scott Palmtag JFA with ORNL in the area of the Exascale Small Modular Reactor (SMR) Modeling and Simulation
- BWR industry FOA project (Scott Palmtag and Maria Avramova)
- VERA Users Group Funding (for CTF development and maintenance – Maria Avramova)

**Opportunities in Modeling and** Simulation





## **CNEC and Post-CNEC**



- CNEC is a 5-year, \$25M consortium awarded to NCSU by the NNSA Office of Defense Nuclear Nonproliferation R&D (NA-22)
  - CNEC was granted a no-cost extension for a sixth year
  - The extension ends September 30, 2020
- NCSU NE led a proposal for a new NNSA Enabling Technologies and Innovation (ETI) consortium in 2018 with 12 partner universities and 13 partner laboratories
  - NNSA selected Georgia Tech's proposal for award
- Defense Threat Reduction Agency (DTRA) issued a solicitation for a \$25M -\$30M/5-year University Research Alliance (URA) on interactions of ionizing radiation with matter (IIRM) - NCSU Material Science and UTK Nuclear Engineering led competing proposals, and NCSU NE was a leading contributor to both proposals, but neither won.
- NNSA will be issuing a solicitation for a new \$25M/5-year Nuclear Science and Security Consortium (NSSC) soon, and NCSU will partner with a western-US university
- On a positive note, SRNL engaged NCSU NE in 3 pre-proposals to NNSA, all of which received a 'green light' from NNSA for a full proposal; those proposals are currently being evaluated by NNSA.
- We have made gradual progress toward establishing a JFA agreement with SRNL, which should enable us to expand our engagement in nonproliferation R&D.

## **Consortium for Nuclear Power (CNP)**



Department of Nuclear Engineering



Consortsium for Nuclear Power CNP Established July 2017 The <u>CNP mission</u> is to promote research and development, innovation, education, and training as well as provision of technical support/expert advice/consultancy services that benefit the nuclear industry and its regulation.

### CNP major goals

- Increase research output
- Attract new sources of funding
- Address grand challenges of nuclear power
- Find and develop new collaborations
- Develop new and novel areas of research
- Become an internationally recognized entity for partnership
- Increase outreach and public awareness
- Provide excellence in education, mentoring and training
- Manage the software UGs such as: CTF UG (core thermal-hydraulic simulator), Core design and fuel cycle optimization UG, HTGR software UG, V&V and UQ software UG, Nodal Simulator UG, etc.

### Industry Advisory Board

- Southern Company Services, Inc., USA
- Tractebel Engineering S.A., Belgium
- Rolls-Royce Power Engineering plc, UK
- Global Nuclear Fuel Japan Co, Ltd.
- Framatome, France-USA-Germany
- NINE Eng Italy
- Discussions for joining with Exelon, INL, Westinghouse, and X-Energy

### University Members

- Penn State, USA
- University of Cambridge, UK
- Imperial College London, UK
- Hacettepe University, Turkey
- University of Florida

# **New Research Areas**



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### NCSU leads in Nuclear Engineering Applications of Data Analytics Coupled with Artificial Intelligence

- Two related projects with DOE led currently by NCSU (PI: N. Dinh, Co-PIs: M. Avramova & I. Bolotnov), which involve industry and national labs:
  - Development and Application of a Data-Driven Methodology for Validation of Risk-Informed Safety Margin Characterization Models – NEUP IRP
  - Development of a Nearly Autonomous Management and Control System for Advanced Reactors – APRA-E MEITNER
- Another 3-year project is starting with BNL on using ML techniques in code validation with PI Maria Avramova
- Another APRA-E project led by X-Energy was awarded with NCSU as a partner – PI Maria Avramova and Co-PIs Jason How and Mihai Diaconeasa

# The new faculty hires bring expertise in the areas we want to develop further

- Design and safety of SMRs
- Advanced reactors and micro-reactors
- Multiscale modeling of nuclear fuel
- Probabilistic risk assessment and reliability analysis
- Computational statistics
- Reduced order modeling
- Machine learning
- Plasma physics









## **International Cooperation Activities**

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- Benefits of the international activities in nuclear engineering to NCSU
  - Increasing the international visibility and recognition
  - · Leading to state-of-the-art graduate research at NCSU
  - Exposing our students to international environments and culture
  - Helping to recruit the best international students for graduate studies at NCSU
  - Bringing externally sponsored projects and student support funding from USA and abroad
- The international activities in our Department involve undergraduate students, graduate students, students, post docs, research scientists, staff and faculty
- Example are the international activities in Nuclear System Modeling and Simulation (M&S) and Verification, Validation and Uncertainty Quantification (VVUQ), which include:
  - Leadership and participation in Nuclear Energy Agency (NEA), OECD activities
  - Leadership and participation in International Atomic Energy Agency (IAEA) activities
  - Bilateral cooperation with GRS, IRSN, UPV, UPM, NECSA, PSI, CEA, including students and faculty exchanges, joint research projects and PhD committees
  - International partnerships in Centers of Excellence such as CNSS/NNR in South Africa
  - · Conducting workshops, seminars, invited short courses
- Consolidation of our international activities in this area through
  - Taking a lead on a multinational, multidisciplinary project within the NEA NEST (Nuclear Education, Skills and Technology) framework
  - Establishing an IAEA Research Collaboration Center at NCSU
- Preparation to participate in the new emerging US DOE Nuclear Cooperation Initiative  $^{\parallel}$



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# Conclusions



- In 2020 the Department is well established and nationally and international recognized as a premier department:
  - = The Department has been very successful in growth and raising external recognition
  - = High relevance of our capabilities to national agenda
  - Credibility in industry, national labs and government agencies as well as strong international connections
  - Clearly, the Department is on a very good trajectory and is in the mode of seeking ways to further improve - a signature of a healthy organization
  - The COVID-19 impact shows the increased role of Distance Education (DE) expanding MNE program, introducing graduate certificates and introducing a DE component/ delivery mode of the PhD DE program
- Our goal for next 5-years is to be the leading Nuclear Engineering Department in the country and in the world with:
  - Preeminent innovative education programs
  - Focus on the growth combined with quality and diversity
  - Top class experimental and computation facilities and capabilities
  - Recognized cutting edge interdisciplinary research addressing the Grand Challenges of nuclear science and engineering
  - Outstanding local and global engagement
  - Organizational excellence based on positivism, collegiality, teamwork and constant improvement