Virginia Tech Nuclear Engineering Program

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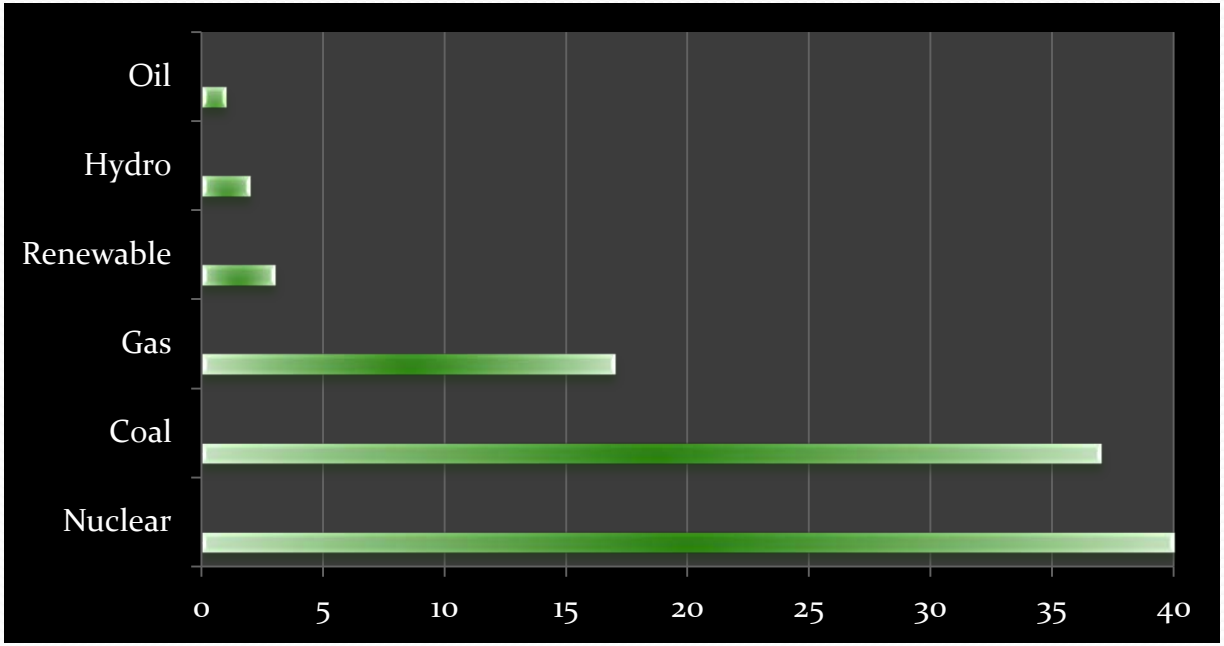
Electricity Generation in Virginia



- Cost of electricity in Virginia is ~10% below the national average.

Virginia - Key Nuclear Organizations

Organization	Major Activities
AREVA NP, Inc.	A major nuclear vendor, which provides various services for nuclear reactors, and designs and builds EPRs, U.S. headquarters in Lynchburg
AREVA & Northrop-Grumman Shipbuilding	Establishing a facility for building heavy components of reactors in Newport News
B&W Nuclear Operations Group	Provides services for DOD and DOE for Navy reactors, located in Lynchburg
B&W Nuclear Energy, Inc.	Provides services, and has designed the Small Modular Reactor (SMR) called mPower, located in Lynchburg
CAER (Center for Advanced Engineering and Research)	Has received necessary funding from State and industry to establish an advanced nuclear reactor control room in partnership with AREVA, and an integral test loop facility for the *mPower* in partnership with B&W, located in Bedford County
Dominion	Generates ~40% of electricity of the State from nuclear power, and is planning to build one new reactor, headquartered in Richmond
Flowserve Industries	A world leader in supplying pumps, valves, seals, automation, and services to the nuclear power, oil, gas, chemical, and other industries. Has a large facility in Lynchburg.
Mitsubishi Nuclear Energy Systems (MNES)	Is a subsidiary of Mitsubishi Heavy Industries (MHI), which supplies commercial industries with efficient, safe, and economical nuclear products and services; signed an agreement with Dominion to build a new Advanced Pressurized Water Reactor (APWR). U.S. headquarters in Arlington
Northrop Grumman Shipbuilding – Newport News Shipyard	Builds U.S. Navy nuclear powered submarines and sole builder of nuclear powered aircraft carriers. Conducts maintenance on all naval nuclear propulsion systems.
Toshiba American Nuclear Energy	Is a subsidiary of Toshiba, supplies nuclear energy services and is promoting the Advanced Boiling Water Reactor (ABWR) in the U.S. Headquarters located in Falls Church.

Former VT Nuclear Engineering Program

- In 1956, as part of the Physics Department, a nuclear engineering program was established, and a research reactor was built in the Physics building at the main campus in Blacksburg. The reactor went on line 1in 1960. This Program later was moved to the College of Engineering.

- In 1985, the nuclear engineering program was terminated and the research reactor was decommissioned.

Current Nuclear Engineering Program (1)

- At request of Virginia's nuclear industry, the Dean of College of Engineering, Dr. Richard Benson, and former of Mechanical Engineering Department Head, Dr. Ken Ball, initiated a Nuclear Engineering Program as part of the Mechanical Engineering Department in 2007.

Current Nuclear Engineering Program (2)

- Faculty:
  - 5 Core Nuclear Engineering
  - 8 affiliate from other departments at VT
  - 1 Adjunct from Northrop Grumman
  - Authorized to hire two more Core faculty

- Degree offering:
  - MS & PhD in Nuclear Engineering (starting Fall 2013)
  - Graduate Certificates in Nuclear Engineering for non nuclear engineers (Since 2010)

- Research:
  - Initiated activities in all areas of application of Nuclear Science Engineering including:
    Nuclear Power, Nuclear Nonproliferation,
    Radiation therapy and diagnostics & Nuclear Policy

Current Nuclear Engineering Program (3)

- **Nuclear Science and Engineering Lab (NSEL) at Arlington (http://nsel.ncr.vt.edu)**
  - In July 2011, under auspices of ICTAS (Institute for Critical Technology and Applied Science), Dr. Haghighat established the Nuclear Science and Engineering Laboratory (NSEL) at the Virginia Tech Research Center in Arlington, Virginia. Drs. Kulkarni and Farkas were recruited to provide leadership in NSEL's activities.

- Enhanced/initiated collaborations with various departments at VT, various organization in Virginia and Beyond

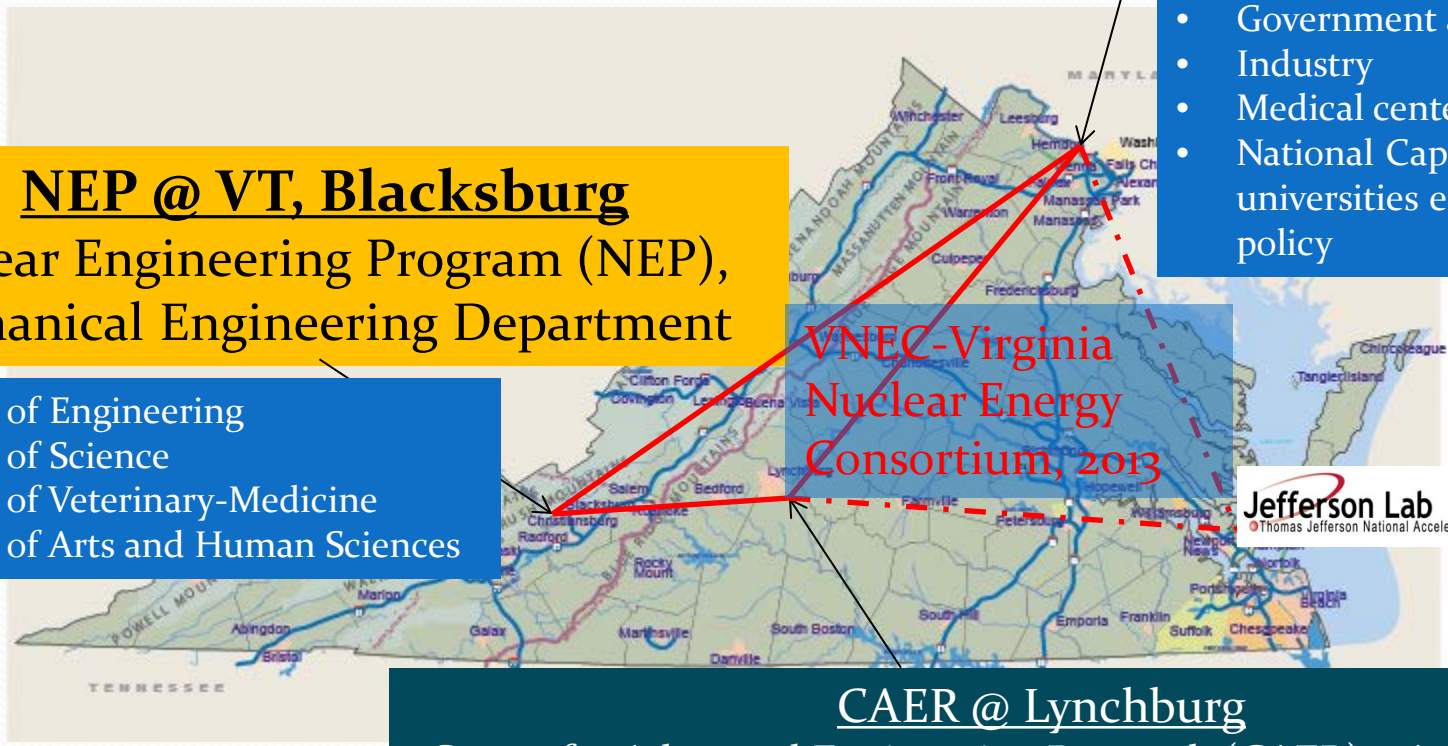
Virginia Tech Nuclear Engineering Program , VT-NEP (multidisciplinary, distance learning)

NSEL @ VTRC, Arlington
Nuclear Science and Engineering Lab (NSEL) – Institute of Critical Technology and Applied Science (ICTAS)

- Government agencies
- Industry
- Medical centers
- National Capital Region (NRC) universities engaged in nuclear policy

NEP @ VT, Blacksburg
Nuclear Engineering Program (NEP), Mechanical Engineering Department

College of Engineering
College of Science
College of Veterinary-Medicine
College of Arts and Human Sciences



CAER @ Lynchburg
Center for Advanced Engineering Research (CAER) – A partnership of State of VA, industry and Universities

AREVA
B&W
Liberty, UVA, VCU, VT

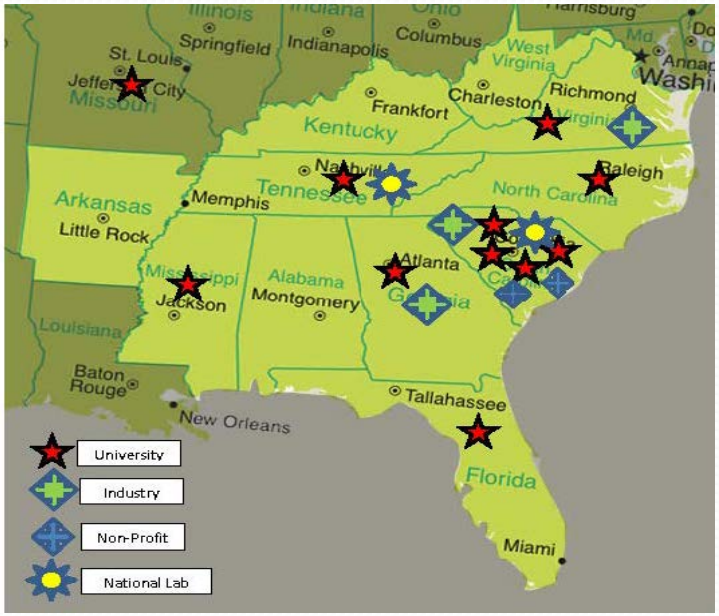
Collaborations beyond Virginia

Southeast Universities

SUNRISE

Nuclear Reactors Institute for Science and Education

- A consortium of universities has established SUNRISE non-profit organization in 2007; it includes:
  - 11 universities, 4 vendors, 2 non-profit organizations, and MOUs with ORNL and SRNL



SUNRISE Mission

- Enhancement of our nation's nuclear workforce, research and technical support following a two-prong approach:
  - Technical
    - Addressing the need for development of **new specialized critical facilities** and supporting laboratories and administrative facilities.
  - Functional
    - Establishment of a single organization that can be utilized by government agencies and the nuclear industry to assist
      - In providing a qualified workforce,
      - To be engaged in nuclear-related research, and
      - To provide technical assistance.

Why Southeast?

- Need for electricity
  - Population growth
  - Lack of other sources of **clean and cheap** energy

- Therefore, the majority of new Nuclear plants in the US are planned or under construction in the southeast:
  - Ongoing Construction of 5 reactors
  - 17 reactors are planned for southeast
  - 6 *mPower* Small Modular Reactors are planned to be build in partnership with TVA (in Tennessee)

SUNRISE activities

- Prof. Haghighat was elected as Chairman of the Board of SUNRISE in 2010; he is serving in his 2nd term

- Prof. Haghighat is leading an initiative for building a Low Power Critical Facility (LPCF)

SUNRISE

- Therefore, we need to build new State-of-the-art flexible and robust nuclear facilities

- Since 2008 , we have examined different nuclear systems, and concluded that low power critical facilities (LPCF's) are the most effective systems, which can provide
  - Flexibility
  - Ease of licensing and construction
  - Ease of operation and use
  - Use for a several important objectives in support of education, research and industry

SUNRISE

- Existing research facilities
  - Are old with an average age of 46 years,
  - Have old/obsolete equipment,
  - Have low availability,
  - Have limited capabilities, and/or
  - Have large uncertainties in geometric and materials information

SUNRISE

- Organized 2012 Symposium on Low Power Critical Facilities, Virginia Tech Research Center, Arlington, VA, March 11-12, 2012 (http://www.cpe.vt.edu/lpcf)

- Selected ORNL for placing the LPCF

- Finalizing a Business Plan, and a planning discussions with potential sponsors

Other events

- Conducted the 13th International Workshop on Particle Transport Simulation of Nuclear Systems (http://www.cpe.vt.edu/transport) (See attachment #4 for an announcement).

- Organized the Forum on Nuclear Regimes: Future Outlook (http://www.ictas.vt.edu/nuclear) (see attachment #6 for an announcement) .

Other activities

- Profs. Kulkarni and Haghighat with help from VT's Department Science and Technology in Society & School of Public and International Affairs (SPIA) has initiated discussions on establishment of a joint

  Center for Nuclear Safety, Safeguards, and Security

  in partnership with George Washington's Elliot School of International Affairs and other National Capital Region (NCR) universities.

- In collaboration with other VT faculty, exploring establishment of certificates in Nuclear Nonproliferation & Nuclear Policy

- Forming alliance with government and non-government organizations

- Exploring establishment of educational programs for training students and professionals from other countries

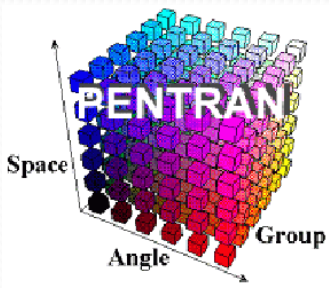
Examples of Research activities

by

Virginia Tech Transport Theory Group (VT3G),
Directed by Prof. Haghighat

- VT³G is engaged in development of hybrid 3-D, multi-scale, parallel particle transport algorithms and codes, and their application to nuclear energy, nuclear security and non-proliferation and radiation therapy and diagnosis.

- In the past 25 years, VT³G has developed numerous particle transport methodologies and formulations. These efforts have led to the development of major computer codes including:
  - Deterministic parallel **PENTRAN** and **TITAN** code systems
  - Monte Carlo **A³MCNP** and **ADIES** code systems with automated variance reduction for neutral and charged particles, respectively.
  - **CPXSD** code system for generation of effective multigroup cross sections.



$$(\mu\frac{\partial}{\partial x}+\eta\frac{\partial}{\partial y}+\xi\frac{\partial}{\partial z})\,\psi_g(x,y,z,\mu,\varphi)+\sigma_g(x,y,z)\,\psi_g(x,y,z,\mu,\varphi)=$$

$$\sum_{g'=1}^{G}\sum_{l=0}^{L}(2l+1)\,\sigma_{s,g'\to g,l}(x,y,z)\,\{P_l(\mu)\phi_{g',l}(x,y,z)+2\sum_{k=1}^{l}\frac{(l-k)!}{(l+k)!}P_l^k(\mu)\cdot$$

$$\left[\phi^k_{C\,g',l}(x,y,z)\cos(k\varphi)+\phi^k_{S\,g',l}(x,y,z)\sin(k\varphi)\right]\}+\frac{\chi_g}{k_0}\sum_{g'=1}^{G}\nu\sigma_{f,g'}(x,y,z)\,\phi_{g',0}(x,y,z)$$

Ongoing projects

- **Nuclear Power**

Developing advanced multigroup algorithms for Simulation of Advanced Reactors (Funded by DOE– Joint with Georgia Tech) (2010-2013)

$$(\mu\frac{\partial}{\partial x}+\eta\frac{\partial}{\partial y}+\xi\frac{\partial}{\partial z})\,\psi_g(x,y,z,\mu,\varphi)+\sigma_g(x,y,z)\,\psi_g(x,y,z,\mu,\varphi)=$$

$$\sum_{g'=1}^{G}\sum_{l=0}^{L}(2l+1)\,\sigma_{s,g'\to g,l}(x,y,z)\,\{P_l(\mu)\phi_{g',l}(x,y,z)+2\sum_{k=1}^{l}\frac{(l-k)!}{(l+k)!}P_l^k(\mu)\cdot$$

$$\left[\phi^k_{C\,g',l}(x,y,z)\cos(k\varphi)+\phi^k_{S\,g',l}(x,y,z)\sin(k\varphi)\right]\}+\frac{\chi_g}{k_0}\sum_{g'=1}^{G}\nu\sigma_{f,g'}(x,y,z)\;\phi_{g',0}(x,y,z)$$

Neutronics modeling of *mPower* Nuclear Reactor (B&W) (started in 2012)

Integral Inherently Safe Light Water Reactor (I^2S-LWR) , led by Georgia Tech with participation of 7 other organizations (recently funded) (funded by DOE IRP, $6 M, 2013-2016)

Nuclear Nonproliferation

- **Nuclear safeguards**

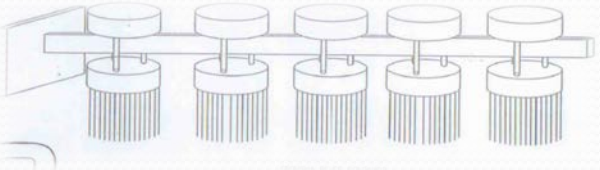
Developed the INSPCT tool for monitoring of spent fuel pool (funded by LLNL)

- Nuclear Security

Developed AIMS (Active Interrogation for Monitoring Special-nuclear –materials)

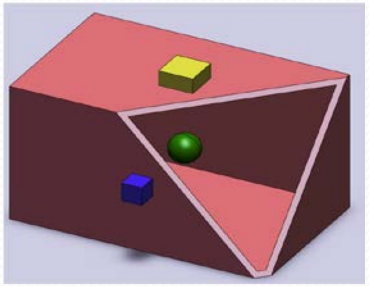
(Funded by NNSA, Joint with Georgia Tech, 2009-1013)

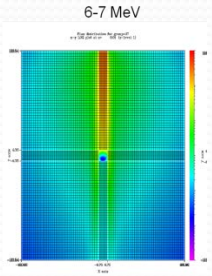
Monitoring of Spent Fuel Pool



	Response(Calculated)								
(x,y)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5
0.5	0.123198	0.230998	0.221266	0.193583	0.166627	0.141523	0.114534	0.083892	0.036611
1.5	0.305453	0.580498	0.561644	0.491674	0.420538	0.353999	0.28285	0.203871	0.087598
2.5	0.467647	0.897903	0.880437	0.770597	0.653747	0.543993	0.427576	0.301569	0.127819
3.5	0.658686	1.271323	1.252983	1.094413	0.922518	0.761393	0.591298	0.410909	0.172554
4.5	0.879337	1.696988	1.669344	1.453015	1.219392	1.002015	0.772365	0.532245	0.222616
5.5	1.029258	1.978009	1.923356	1.665877	1.394836	1.14574	0.880125	0.605581	0.253192
6.5	0.57336	1.093457	1.058167	0.914234	0.765146	0.628852	0.482792	0.332139	0.139652
	Response Difference								
(x,y)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5

Inspection of Containers

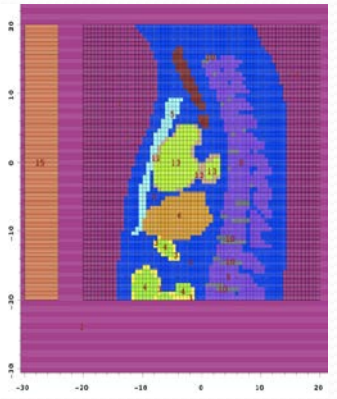


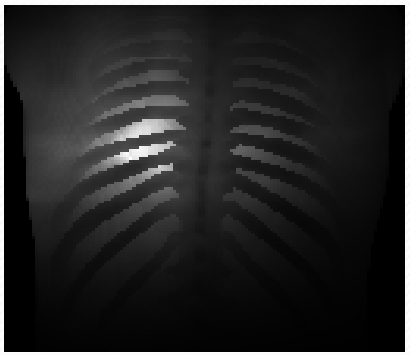


- **Radiation diagnostics**

Developing algorithms for improvement of SPECT imaging and reduction radiation exposure

SPECT Image of heart using TITAN





A3) TITAN: posterior

Nuclear Power in 21st century

- **Needs**
  - **Qualified workforce**
  - **R&D (e.g., enhancement of *existing reactors*, *Used nuclear fuel* reprocessing and storage, Advanced *fuel cycles*, Advanced *reactor design* in conjunction with *nuclear nonproliferation* considering Safety, security & Safeguards by design - *3SBD*)**
  - **Effective Public information**
  - **Policy**
- **How?**
  - **Invest in**
    - **Establishing and enhancing nuclear education & training**
    - **Building state-of-the-art facilities**

Thanks!

Questions?