Educating the Next Generation of Nuclear Experts: the Nuclear Science and Security Consortium 10-Year Experience

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University of California, Berkeley
Lawrence Livermore National Laboratory
With an urgent goal to develop well-rounded professionals with a working knowledge across all disciplines of nuclear science and security needed to meet its nuclear security mission, DOE/NNSA NA-22 established the Nuclear Science and Security Consortium (NSSC) in 2011 and provided $50 M over the 10-year period for E&R&D.

The NSSC’s primary objectives are to:

- **recruit and train top students** in relevant nuclear disciplines,
- connect students with a **core set of disciplines** that support the nonproliferation and nuclear security mission, and
- **expand national laboratory collaboration** to provide students the opportunity to engage deeply in research under the guidance of lab staff scientists.
SUCCESS PIPELINE MODEL

- **Seven Universities Coordinating Coursework and Experience from Student to Scientist in a Partnership for Identifying and Preparing Educated Laboratory-Integrated Nuclear Experts**

- Start with a multidisciplinary team of experts from academia and national labs. Develop effective management and organizational structure. Utilize the Lab researchers expertise by creating joint appointments and adjunct positions at universities.

- “End-to-end approach” – broad recruitment of best undergrads and grads, focusing on those who combine (i) broad perspective, (ii) solid science & engineering foundation, (iii) highly developed specialization.

- Develop advanced E&R&D programs, enriched with summer schools, workshops, webinars, internships at the labs. Expose students to the lab environment and work on their retention. Develop effective reporting and metrics of success.
NSSC draws students and scholars together in unconventional ways, replacing the boundaries that separate disciplines with more inclusive SCIENCE-TECHNOLOGY-POLICY interface.
SUCCESS PIPELINE MODEL
Strong Teams of Experts

- NSSC partner universities currently include UC Berkeley as the lead, with MSU, UCD, GWU, TAMU, UTK, and UNLV.

- Involvement of 63 faculty and 17 specialists in NSSC’s E&R&D.

- NSSC partner laboratories: LBNL, LLNL, LANL, ORNL, and SNL with close to 200 lab scientist involved in mentorship and summer programs.
SUCCESS PIPELINE MODEL
Effective Management and Oversight

NNSA DNN

NSSC EXECUTIVE TEAM

PI/Director: Jasmina Vujic - UCB
Executive Director: Bethany Goldblum - UCB/LBNL
Deputy Executive Director: Jason Hayward - UTK
NNSA Liaison: Kai Vetter - UCB
Director for Laboratories: Lee Bernstein - UCB/LBNL

ADVISORY BOARD

Chair - Carol Burns - LANL
Roger Falcone - UCB
Miriam John - SNL (retired)
David McCallen - UN Reno
Benn Tannenbaum - SNL
Catherine Romano - ORNL
Mavrik Zavarin - LLNL

POINT OF CONTACT COUNCIL

UNIVERSITY
Chris Cahill - GWU
Sean Liddick - MSU
Cody Folden - TAMU
Mani Tripathi - UCD
Frederic Poineau - UNLV
Jason Hayward - UTK

LABORATORY
Margie Root - LANL
John Valentine - LBNL
Vladimir Mozin - LLNL
Dave Williams - ORNL
David Peters - SNL

NSSC SUPPORT STAFF

Program Manager: Charlotte Carr
Financial Analyst: Derek Johnson
SUCCESS PIPELINE MODEL
Effective Management and Oversight

• Effective NSSC management:
  – The Executive Team meets every week.
  – The Leadership Team (the university and lab POCs) meets every month.
  – The Advisory Board meets once a year.

• Effective NSSC student oversight:
  – Daily communication with academic advisors and lab mentors.
  – Weekly meetings of research groups.
  – Monthly participation in seminars.
  – One Working Session per semester – the NSSC students connect and learn about the research that other NSSC students are conducting.
  – One NSSC Annual Workshop – held in one of the partner national laboratories – providing an opportunity for NSSC students to present their work, and to meet with lab scientists.
  – Each student required to attend one summer program at the labs and one policy boot camp.

• Effective NNSA oversight:
  – UPR annual showcase.
  – Schubert Reviews.
## SUCCESS PIPELINE MODEL

### Performance Metrics

- **Number of People Supported**
  - Undergraduate students
  - Graduate students
  - Postdocs
  - Faculty (Jr./Senior)
  - Lab-based Adjuncts

- Degrees awarded

- Students conducting research in-residence at National Labs

- Students working on Lab-directed projects

- Number of peer-reviewed publications

- Number of presentations

- Number of honors and awards

## Metrics of Effectiveness

- **Pipeline of Graduating Students**
  - Continuing to Graduate School
  - Position at a National Lab
  - In the Nuclear Security Industry
  - In Nuclear Security Related Academia
  - In Nuclear Security Related Other Government
SUCCESS PIPELINE MODEL
Research and Educational Model

We attract the best and brightest students from our 7 partner institutions

Match their interests to our research focus areas

Every NSSC Fellow is required to have

- Academic Advisor
- Lab Mentor

To help facilitate each student’s involvement in

- Lab Directed Projects
- In-Residence Research

In collaboration with 5 National Lab Partners

Transition students into careers at the national labs supporting the NNSA National Security Agenda!
NSSC Personnel
2011 - Present

551 people have been supported by NSSC

Completed
311 degrees:
114 Ph.D. degrees
81 M.S. Degrees
116 B.S. Degrees

Undergraduate
31.8%

Specialists
3.1%
Faculty
11.4%
Postdocs
8.5%

Grad Students
45.2%

Gender ratio of NSSC scholars
Female * 
30.7%
Male
69.3%

*The student body of the College of Engineering at UC Berkeley is 28.6% female.
NSSC Metrics Overview
2011 - Present

364 Peer Reviewed Publications


188 Awards

Daine Danielson (UCD) and Travis Smith (UTK) won 2019 Innovations in Nuclear Technology R&D Awards

520 Poster Presentations

Kevin Glennon (TAMU/LLNL) presented “A Forensic Investigation of Legacy Separated Pu” at LANL. Kevin also won Outstanding Presentation in Chemistry at LANL

801 Oral Presentations

Stephanie Lyons (MSU/PNNL) "β-decay of neutron-rich Co with Total Absorption Spectroscopy" Nuclear Seminar, Technical University Darmstadt, Germany.
## NSSC Sponsored Courses

**NSSC has sponsored 10 courses held at four partner institutions**

<table>
<thead>
<tr>
<th>Course</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear Security: The Nexus Between Policy and Technology</td>
<td>UC Berkeley</td>
</tr>
<tr>
<td>A Hands-On Introduction to Radiation Detection</td>
<td>UC Berkeley</td>
</tr>
<tr>
<td><strong>Special Topics: Nuclear Data</strong></td>
<td>UT Knoxville</td>
</tr>
<tr>
<td>Radiochemical Methods in Nuclear Technology and Forensics</td>
<td>UC Berkeley</td>
</tr>
<tr>
<td>Radiation Detection and Nuclear Instrumentation Lab Course</td>
<td>UC Berkeley</td>
</tr>
<tr>
<td>Advanced Concept for Radiation Detection &amp; Measurements</td>
<td>UC Berkeley</td>
</tr>
<tr>
<td><strong>Special Topics: Nuclear Data</strong></td>
<td>UC Berkeley</td>
</tr>
<tr>
<td>Nuclear Criticality Safety</td>
<td>UC Berkeley</td>
</tr>
<tr>
<td>Nuclear and Radiochemistry</td>
<td>UC Irvine</td>
</tr>
<tr>
<td>Designed Emphasis in Nuclear Science (DENS)</td>
<td>UC Davis</td>
</tr>
</tbody>
</table>

**Special Topics: Nuclear Data**
- with Prof. Heilbronn and Prof. Sobes

**Nuclear Security: The Nexus Between Policy and Technology**
- with Prof. van Bibber and Prof. Nacht

**A Hands-On Introduction to Radiation Detection**
- with NSSC Specialist Dr. Ali Hanks
NSSC Fellows and Affiliates Conducting In-Residence Lab Research

National Laboratory

- LBNL: 36, 34, 20, 28
- LLNL: 16, 17, 19
- SNL: 17, 6, 4
- LANL: 26, 18
- ORNL: 16, 12
- Other: 5, 4, 1

Years:
- 2016-2017
- 2017-2018
- 2018-2019
- 2019-2020
- 2020-2021
~43% of NSSC alumni are currently* in careers in the national labs or other government positions (DOD, DOE, NNSA, DTRA, Air Force, US Navy, US Army, NNSS, Intelligence)

*These data reflect current appointments. A total of 131 NSSC alumni have been employed in positions in the National Labs or Other Government, with some then moving on to other fields.
 NSSC Summer Programs

NSSC has supported 40 Summer Schools

UC Davis Nuclear Analytical Techniques Summer School

UC Berkeley Radiation D&M Summer School

UNLV Radiochemistry Summer School

NSSC LANL Keepin Nonproliferation Science Summer Program

GW Boot Camp on Nuclear Security Policy

*Many Summer 2020 programs were cancelled due to COVID-19
NSSC-LANL Keepin Nonproliferation Science Summer Program

Goals:

- Create **working relationships** between NSSC students and LANL scientists
- Increase number of students performing **programmatic research** with LANL
- Turn research and training into **careers at the national laboratories**

<table>
<thead>
<tr>
<th>Dates</th>
<th>NSSC Participants</th>
<th>Other Participants</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 22 - Aug 14, 2020</td>
<td>2</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>June 17 - Aug 9, 2019</td>
<td>5</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td>June 18 - Aug 8, 2018</td>
<td>14</td>
<td>13</td>
<td>27</td>
</tr>
<tr>
<td>June 19 - Aug 1, 2017</td>
<td>12</td>
<td>8</td>
<td>20</td>
</tr>
</tbody>
</table>

2020 program held virtually

Post-program survey of 2020 participants:

- **90%** of students found this program to be beneficial or very beneficial to their professional development.
- **100%** of students are likely or very likely to recommend this program to others.

At the end of the summer program all participants present oral **“lightning presentations”** for LANL personnel on their summer research project.
Public Policy & Nuclear Threats Boot Camp (PPNT&GW)

Goals:

- Establish a foundation for understanding the national security mission
- Provide participants with a foundation on the historical, legal, ethical, and technical aspects of nuclear weapons policy issues
- Facilitate collaboration between scholars from the technical and social sciences
- Provide networking opportunities with nuclear policy professionals

<table>
<thead>
<tr>
<th>Dates</th>
<th>NSSC Students</th>
<th>Other Students</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW 2019 (6/9-6/21)</td>
<td>20</td>
<td>6</td>
<td>26</td>
</tr>
<tr>
<td>GW 2018 (6/11-6/22)</td>
<td>11</td>
<td>9</td>
<td>20</td>
</tr>
<tr>
<td>PPNT 2020 (7/26-8/15)</td>
<td>13</td>
<td>255</td>
<td>268</td>
</tr>
<tr>
<td>PPNT 2019 (7/18-8/7)</td>
<td>1</td>
<td>26</td>
<td>27</td>
</tr>
<tr>
<td>PPNT 2018 (7/29-8/7)</td>
<td>1</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>PPNT 2017 (7/16-7/25)</td>
<td>1</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>PPNT 2016 (6/19-6/29)</td>
<td>15</td>
<td>11</td>
<td>26</td>
</tr>
<tr>
<td>PPNT 2015 (6/21-7/11)</td>
<td>23</td>
<td>7</td>
<td>30</td>
</tr>
<tr>
<td>PPNT 2014 (7/6-7/16)</td>
<td>15</td>
<td>8</td>
<td>23</td>
</tr>
<tr>
<td>PPNT 2013 (8/4-8/18)</td>
<td>1</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>PPNT 2012 (8/5-8/25)</td>
<td>0</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

NSSC Fellows from UCB, MSU, and UTK participate in a mock congressional hearing.
Objectives:
- Support the educational process
- Provide data from laboratory demonstrations
- Benefit university research projects

Instrumentation:
- Neutron generators: DT, DD, Cf, Cm, (α,n)
- Gamma-ray detectors: HPGe, LaBr₃, CZT, NaI(Tl), etc.
- Neutron detectors: ³He, EJ-301, EJ-309, Stilbene
- Imaging: X-Ray and Neutron transmission

Materials:
- Gamma-ray and neutron sources
- Low- and high-Z shielding
- Pu material samples
- U mass and enrichment standards
- Containers and enclosures

Evaluation of prompt gamma-ray emissions from neutron interrogation of meteorites
NSSC Webinars, Workshops, Panels

Monthly webinars featuring nuclear science and policy as well as numerous workshops, panels, and special events

Dr. Nicholas Scielzo, LLNL presented webinar on “Improving beta-decay studies for fundamental science and applications” in 2017

Provided support 22nd technical meeting of the Nuclear Structure and Decay Data Network of the International Atomic Energy Agency in 2017

Assisted the organization of Workshop on Nuclear Data Needs and Capabilities for Applications 2015

NSSC Fellows touring the NIF as part of the NSSC 2019 Fall Engagement Workshop
Nuclear & Particle Physics Focus Area

Barbara Jacak (lead)
Lee Bernstein
Bethany Goldblum

Sean Liddick (co-lead)
Alexandra Gade
Artemis Spyrou
Hiro Iwasaki

Mani Tripathi
Robert Svoboda

Research Areas Include:
- Cross section measurements
- Neutrino physics
- Detectors for charged particles, photons, and neutrons
- Structure of bound and unbound nuclear states

**Crosscutting with Nuclear Data, Modeling and Simulation**

Vincent Fischer, UCD
ANNIE Phase II construction
Lab Mentor: Steven Dazeley
Nuclear Data Crosscutting Area

Research Areas Include:
- Fission fragment distribution and beta-decay studies
- Forensics/delayed gamma-ray measurements
- Statistical nuclear properties for nuclear reaction modeling
- Topical evaluations for nonproliferation
- Nuclear data architecture development
- \((n,f), (n,n')\) and \((n,\gamma)\) experiments
- “Baghdad Atlas” \((n,n'\gamma)\)

UCB/LLNL team: L. Bernstein, B. Goldblum, T. Laplace, D. Bleuel, J. Brown, J. Gordon
\((n,xny)\) data for neutron scattering and active interrogation
Recent Graduates
Highlights

Stephanie Lyons  Daniel Hellfeld  Madhuri Kumari  Rachel Mersch

Matthew Tweardy  Aaron Manalaysay  August Ridenour  Milos Atz
Acknowledgements

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Radiochemistry & Forensics Focus Area

Ken Czerwinski (lead)  
Frederic Poineau

John Arnold (co-lead)  
Peter Hosemann

Cody Folden

Howard Hall

Chris Cahill

Research Areas Include:
- Molecular nuclear forensics
- Mass spectrometry for forensics applications
- Synthesis and characterization
- Chemical separations and innovative solvents

Athena Gallardo, UNLV  
Now at LANL.
Analyzing coral from the Bikini Atoll  
Lab Mentor: Terry Hamilton, LLNL
Nuclear Engineering Focus Area

**Prof. Massimiliano Fratoni (lead)**
Prof. Peter Hosemann
Prof. Jasmina Vujic

**Prof. Philippe Bardet (co-lead)**

**Research Areas Include:**
- Proliferation resistance of advanced fuel cycles
- Materials science
- Advanced tools for safeguards measurements

**Matthieu Andre, GWU**
*Modeling of nuclear plumes*
Lab Mentor: Marianne Francois (LANL)
Radiation Detection & Nuclear Instrumentation Focus Area

Kai Vetter (lead)
Bethany Goldblum

Jason Hayward (co-lead)
Eric Lukosi
Chuck Melcher
Mariya Zhuraleva

Research Areas Include:
- Detector materials
- Detector development and characterization
- Radiation imaging and advanced concepts

Kalie Knecht, UCB
3D Compton Imaging with Scene Data Fusion in Relevant Environments
LBNL mentor: Dan Hellfeld (former NSSC fellow)

Sean Liddick

Mani Tripathi
Robert Svoboda
Eric Prebys
Emilija Pantic
Research Areas Include:
- Neutral particle transport on advanced architectures
- Methods development for forensics applications
- Physics-specific code development and verification
- Nuclear data benchmarking
- Reactor disaster monitoring through antineutrino detection

Adriana Sweet, UCB
Statistical Nuclear Properties of $^{93}$Sr for National Security Applications

Lab Mentor: Darren Bleuel, LLNL

Nuclear Properties
- Nuclear Level Density (NLD)
- $\gamma$-Ray Strength Function ($\gamma$SF)
Nuclear Security Policy Crosscutting Area

Crosscutting Area Lead: Michael Nacht (UCB)

Partner Institutions

2018 GW Boot Camp on Nuclear Security Policy

Nuclear Security: The Nexus Between Technology and Policy
Grad-Level Course at UC Berkeley (with LANL Partnerships and Pipeline Office)