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Illustration by Chris Brigman

Perspectives from a DOE Lab on CSE Education and Workforce Needs

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Credit to Karen Devine (Sandia) and Rich Vuduc (Georgia Tech) for help with this talk!

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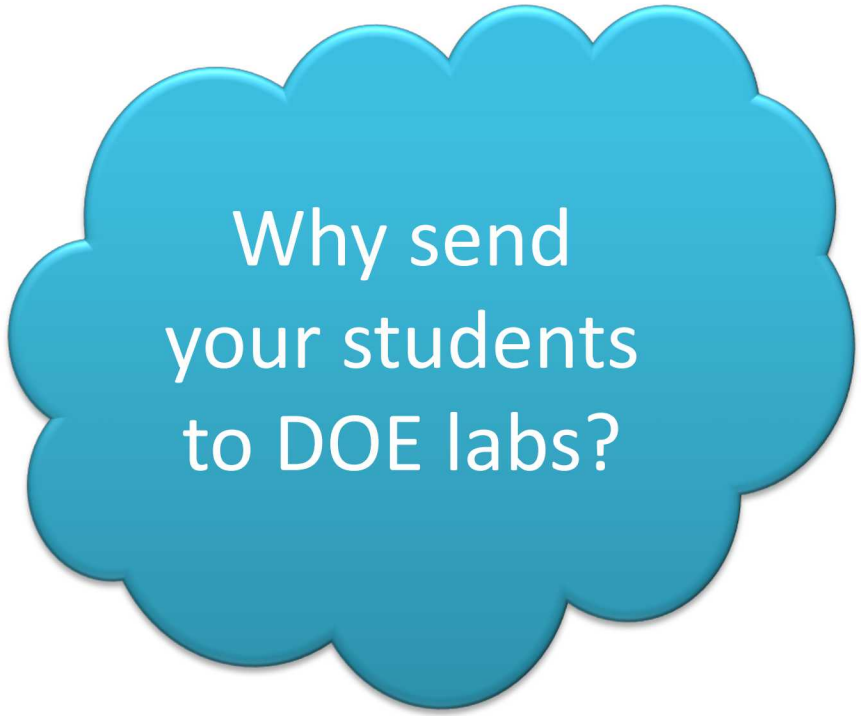
Recommendations Preview

- Make side projects integral to the program
- Explicitly develop communication skills
- Require major programming project
- Encourage leadership and teaming
- Develop “soft skills” curriculum

CSE practitioners at DOE Labs are…



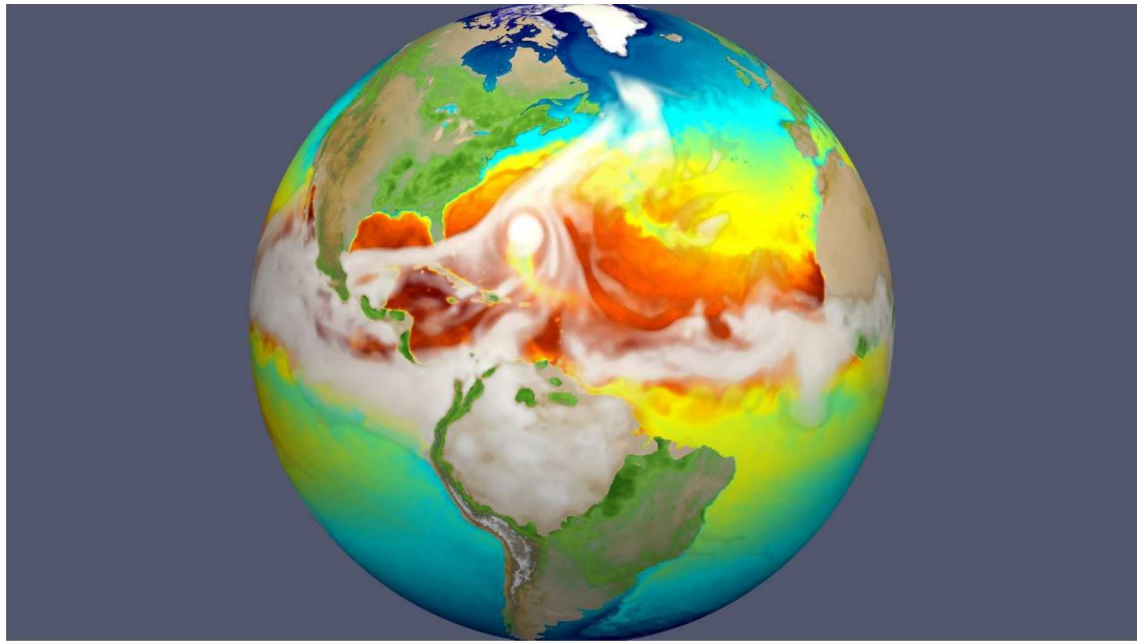
- Working on real-world problems
- Contributing to interdisciplinary teams
- Bringing “academic” research to life
- Applying their skills to problems of national interest
- Gaining a unique vantage point
- Both consuming and producing research
- Setting many of the goals in the field
- Co-training the next generation of researchers
- Collaborating with universities, other labs, and industry
- Enmeshed in large-scale R&D operations rivaling anything in academia

Department of Energy (DOE) Labs

- GoCo – Government-owned, contractor-operated
- All are Federally Funded Research and Development Labs (FFRDCs)
  - Public-private partnerships, conducting research for the United States Government.
  - Currently 42
- National Nuclear Security Administration (NNSA) Labs
  - Sandia – Albuquerque, NM and Livermore, CA
  - Los Alamos – Los Alamos, NM
  - Lawrence Livermore – Livermore, CA
- Office of Science Labs
  - Lawrence Berkeley – Berkeley, CA
  - Argonne – Chicago, IL
  - Oak Ridge – Oak Ridge, TN
  - Pacific Northwest – Richland, WA
  - Brookhaven – Upton, NY
  - And more…

Sandia is the Largest DOE Lab

- FY17 R&D Funding: $3,073M
  - $1,821 M DOE NNSA
  - $ 241 M DOE Office of Science
  - $1,111 M Strategic Partnerships
  - *Compare to ~$700 M at UC Berkeley*
- FY17 Workforce
  - 10,800 Regular
    - 1905 PhDs
    - 4161 MS
    - 2046 BS
    - *Compare to ~1600 full-time faculty at UC Berkeley*
  - 220 Postdocs
  - 760 Students

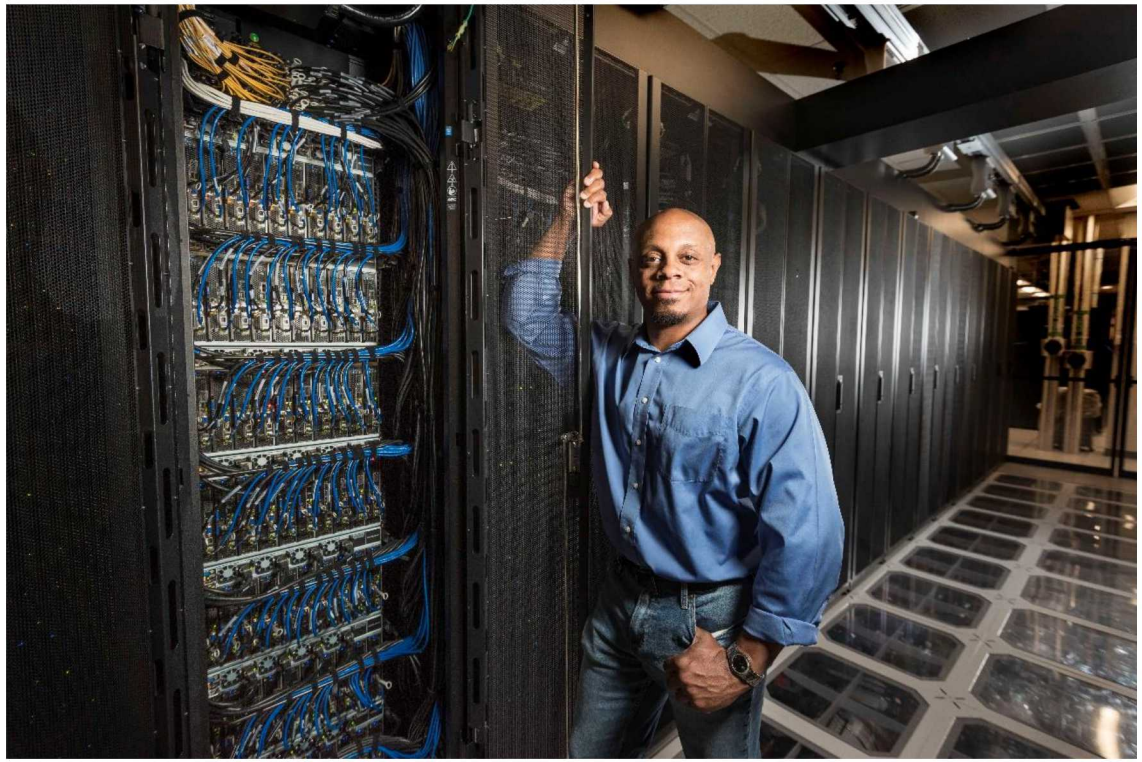


The Energy Exascale Earth System Model is the work of eight Department of Energy labs, including Sandia National Laboratories, and several universities. The image shows a supercomputer simulation of a hurricane approaching the U.S. east coast and the evolving sea surface temperatures in its wake. This type of hurricane would have surface winds exceeding 150 mph and would leave cold wakes that are 2 to 4 degrees Celsius cooler than their surroundings. This simulation also represents how the resultant cold wake would intensify the next hurricane. (Photo courtesy of Oak Ridge National Laboratory).

R&D Careers at Sandia Require Technical Depth, Flexibility, and Soft Skills

- An R&D career can feature
  - Academic-style research
  - Large-scale software development
  - Applications specialization
  - Project management
  - Management
  - All of the above!

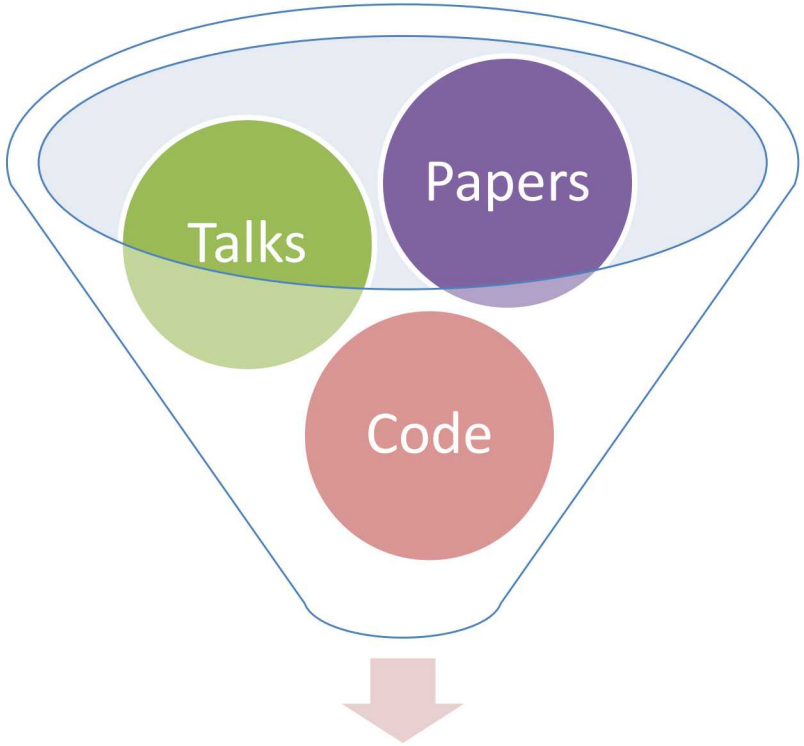
- Work delineated by projects
  - 100% soft money, requires long-term flexibility
    - Long-running efforts like ASC program
    - Limited duration grants from DOE ASCR, DARPA, etc.
  - Teaming is essential
    - Each project is a team of 2-25 people
    - Individuals usually work on 2-3 different projects
    - Opportunities for project/subproject leadership
  - Communication is critical
    - Within team and with other teams
    - With current and future sponsors
  - Ultimately R&D staff grow to define the projects
    - Applying cutting-edge research to important problems
    - Proposing future-looking research projects



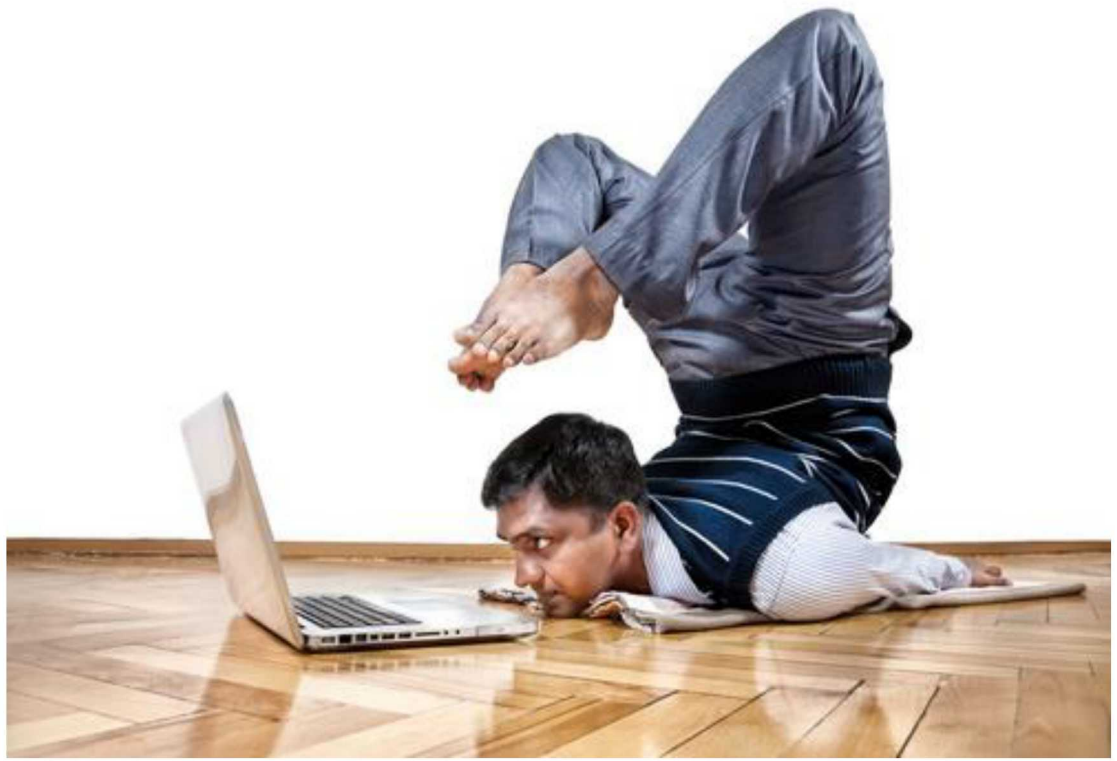
Pictured: Warren Davis, Sandia National Labs
From: *Three Sandia Labs researchers earn national honors in leadership and technology*,
Sandia Lab News Release, Feb. 11, 2019

Continued Need for Technical Depth, with Expanding Scope of Topics

- Topics
  - Numerical analysis
  - Partial differential equations
  - Linear/multilinear Algebra
  - Nonlinear optimization
  - Scientific Computing
  - Theoretical computer science
  - Applied probability & statistics
  - Machine learning
- Computing Skills
  - C++, C, Fortran
  - Parallel Computing – MPI/OpenMP
  - Python, Java, Julia
  - MATLAB, R



Technical Flexibility Indicative of Long-Term Lab Career Fulfillment and Success



Prototypical Sandian flexibility

- Motivators
  - Changing landscape of problems
  - Working on multiple projects
- Recommendation: Make side projects integral to the program
  - Summer internship
    - National labs
    - Industry
  - Within-university side project
    - Emphasize different, but related skills
    - Working with another group
  - Consulting on interdisciplinary project
    - Student is the “math/compute” expert
    - Also develops teaming, communication skills, problem solving

Communication is of Critical Importance, Including Informal Exchanges

- Recommendation: Explicitly Develop Communication Skills

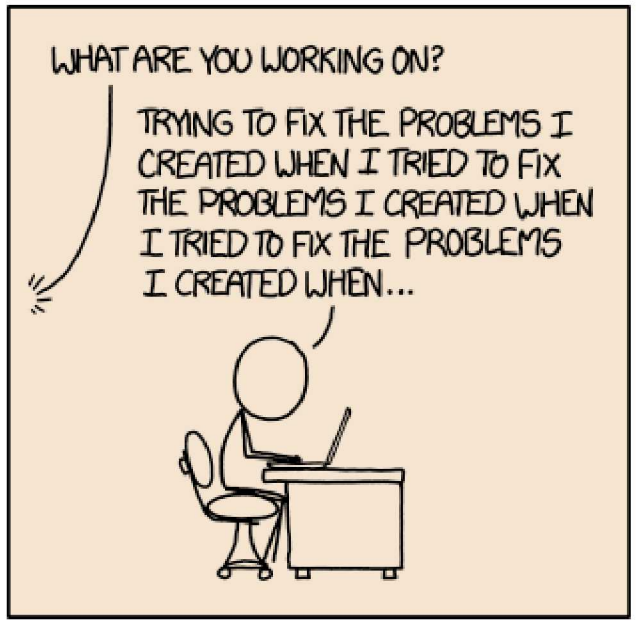
- Formal communications
  - Technical Papers, Proposals
  - Seminars, Conference Talks
  - Research statements and CVs

- Informal communications
  - Emails, Texts, Social Media
  - Meetings, Phone calls, Video chats
  - Elevator speeches

- Consider Contexts for Communicating
  - Establishing expertise (e.g., interviewing)
  - Comprehending the work of others!
  - Interdisciplinary discussions seeking a common language
  - Understanding application problem
  - Setting a vision for the future
  - Networking

Teaming computer science, statistics, and math at Sandia
(Kina Winoto, Cliff Anderson-Bergman, Me, Justin Jacobs)

Software Knowledge now Includes Code Quality as well as HPC Chops



- Growing importance of software due to complexity of what the labs are trying to accomplish!
  - Requires advanced skills, beyond just "programming chops"
- DOE labs value in-depth software know-how
  - C++ preferred (also C, Fortran for some groups)
  - Python, Java, Julia, R, MATLAB
  - Parallel programming a *huge* plus
- Also need collaborative programming skills
  - Clean code, well-documented
  - Version control systems like GIT
  - Reproducible
- Recommendation: Require major programming project
  - Required for PhD candidacy
  - Recommend team-based with need for interfacing
  - Should also use big open-source scientific libraries like Trilinos
  - Code reviews with emphasis on readable and understandable code

Leadership & Teaming Skills

- Recommendation: Encourage leadership and teaming

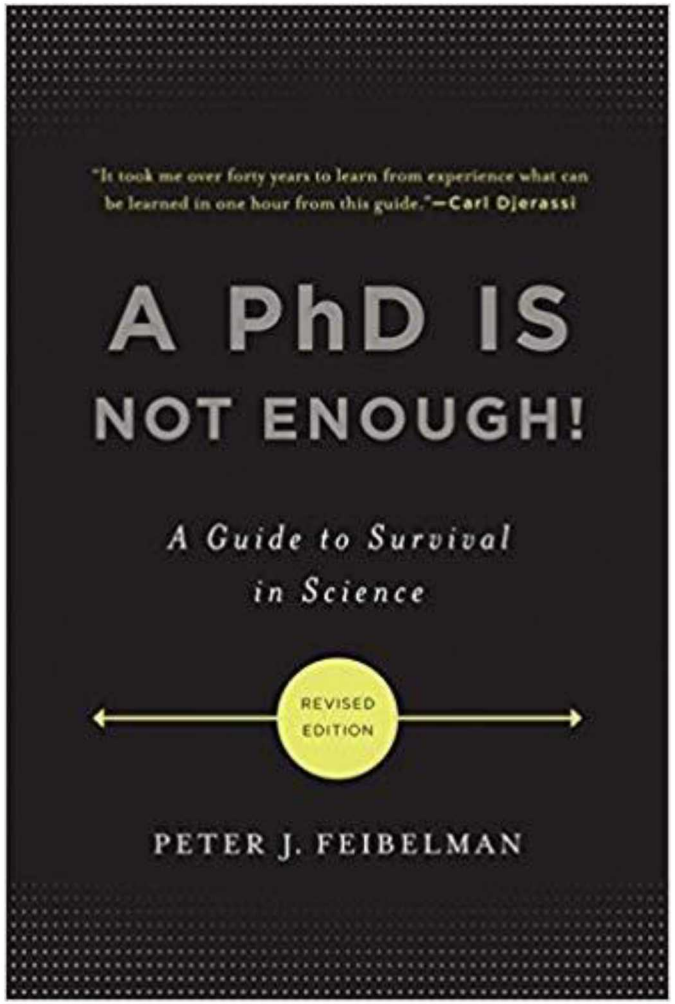
- Motivation: Stand out among job applicants
  - Also contributes to long-term success
  - Encourage via prizes, competitions, other activities
- Professional Leadership
  - Organize student seminar/reading group
  - Officer of student association, like SIAM Chapter
  - Graduate student representative to department committees
  - Workshop, minisymposium organization
- Extra Teaming Skills
  - Success in team-based competitions (like Kaggle)
  - Involved with student activities

Most PhD Program Focus on Technical Training but Omit Soft Skills

- Recommendation: Develop "soft skills" curriculum

- Most PhD programs focus on formal training
  - Mathematics, statistics, computer science coursework
  - Broad training stops at the MS level
  - PhD becomes specific, sometimes overly so

- Informal training comes from mentoring, peer groups
  - Written & oral communication skills
  - Computer programming, especially for larger-scale projects
  - How to work in teams
  - Finding and securing internships
  - Leadership development
  - Professional ethics



Recommendations for PhD Programs

Make side projects integral to the program	• Promote internships at labs and project with other research teams • Nurture consulting for interdisciplinary teams
Explicitly develop communication skills	• Don't forget informal communication, like emails and elevator speeches • Listening and asking questions also part of communicating
Require major programming project	• Recommend it as a requirement for PhD candidacy • Emphasize collaboration and review codes as if they were math proofs
Encourage leadership and teaming	• Provide opportunities to lead reading groups, compete in teams • Inspire both teaming and leadership via small prizes
Develop "soft skills" curriculum	• Formalize development of soft skills via classes taken for credit • Currently informal via mentors or peer-to-peer, if at all