

Stanford University, June 21, 2017

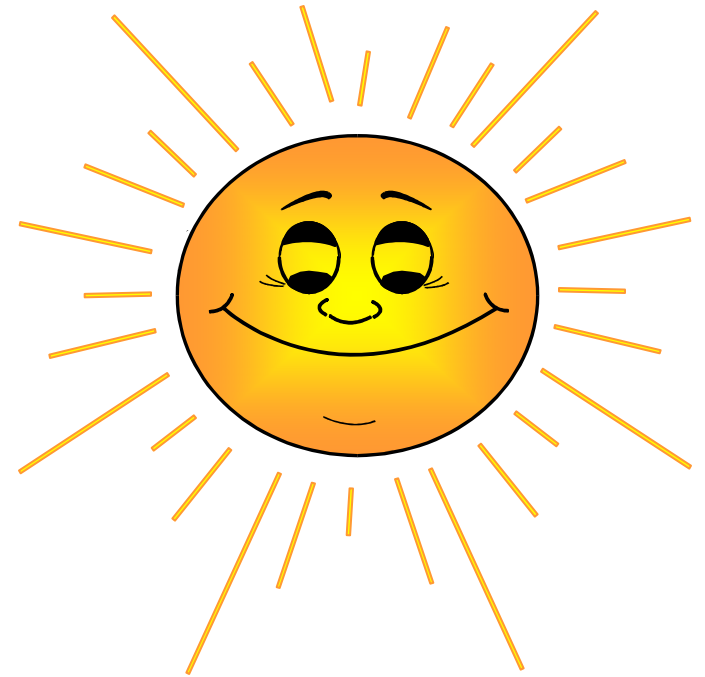
# A Device to Systems Perspective on Modeling Nanoelectronic Systems

Mark Lundstrom  
Lead Investigator  
NEEDS

Purdue, MIT, Berkeley, Stanford

# The era of Accelerated Technology Innovation

- Differentiated technology will become a competitive advantage.
- Technology innovations will be driven by the pressing needs of society
- Technology innovation will become more diverse and less predictable.



Dennis Buss, "Microelectronics Industry in Transition,"  
<http://nanohub.org/resources/19576>

# 21<sup>st</sup> Century Faculty

October 6, 2016

Tenure-track position at Harvard University

Tenure-track Position in Electrical Engineering

The Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS) seeks applicants for a position at the tenure-track level in Electrical Engineering. ...

**We are particularly interested in candidates with sufficient breadth to be able to work across multiple levels along the continuum of EE topics: materials, devices, circuits, systems, algorithms and theory.**

# 21<sup>st</sup> Century Electronics

Today electronics is in transition to a new era:

- Informed by a wider range of science
- Driven by a broader set of challenges
- Important to more and more companies

NEEDS has been about setting the stage for this exciting new era.

“NEEDS should be developed with the intent to...promote the integration of nanodevices in circuits and products.”

***Systems and applications***

***Compact modeling and simulation***

**Compact models: Deep physics / SPICE compatible**

***Model-driven understanding and exploration***

***Experimental, theoretical, and computational nanoscience***

“...the NSF anticipates that the majority of the ... contribution will be at the fundamental level ....”

# System-driven Research

- Stochastic nanomagnets as building blocks for brain-like systems
- (Datta-Purdue)
- Simulation of circuit-level accommodation of noise in biosensors
- (Alam-Purdue)
- Forward and inverse design of PV systems including variability and reliability
- (Alam-Purdue)
- Robust optimization of silicon optical system using compact models and UQ (Daniel-MIT)
- Pattern recognition in big data images with monolithic oscillators in CMOS (Daniel-MIT)
- Model-driven approach to science to systems research for CNT computers (Wong/Mitra-Stanford)
- Design and fabrication of graphene dot product nanofunctions (Pop-Stanford)

# NEEDS Infrastructure

Goal 1) Compact models

Goal 2) Tools and processes

Goal 3) Educational resources for a new era

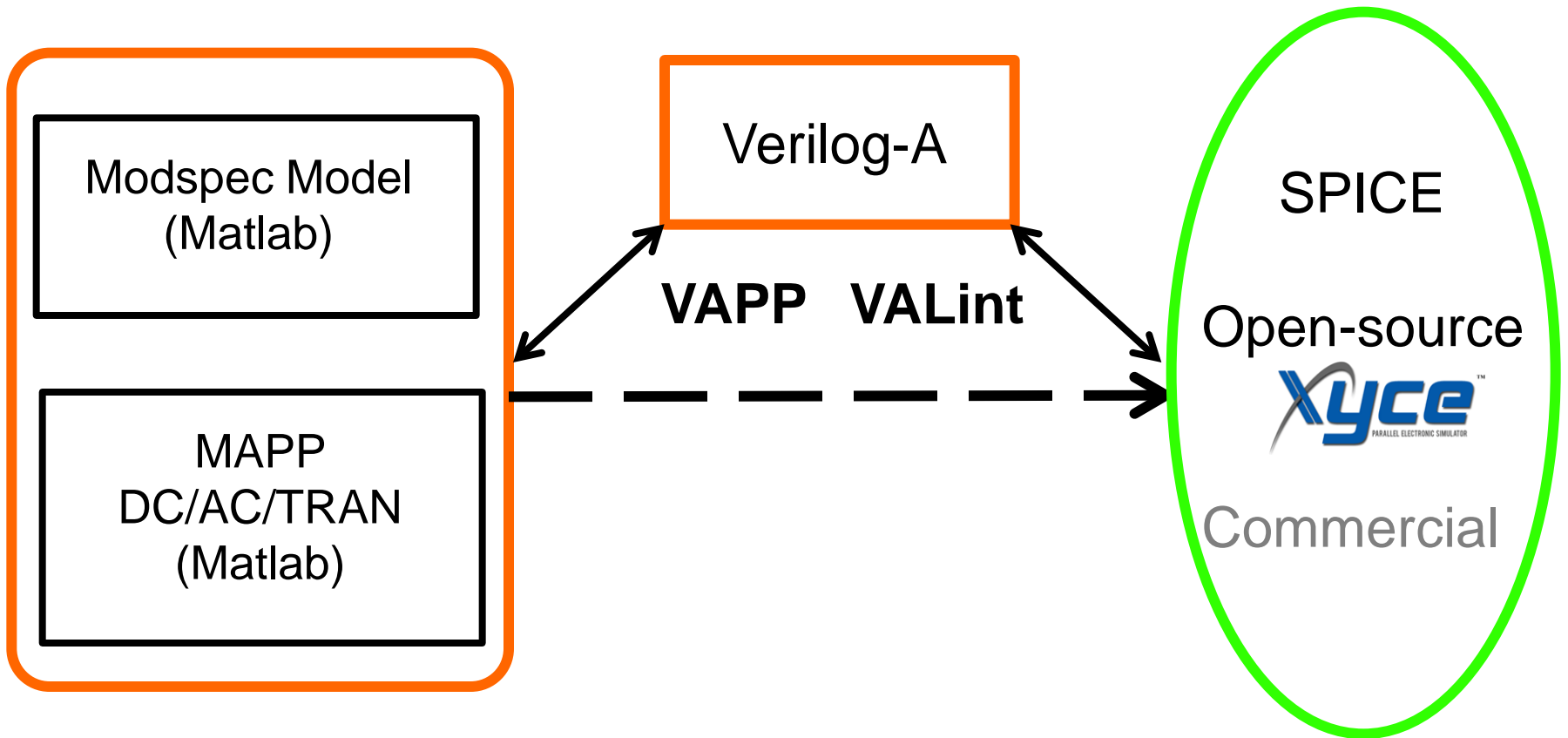
Goal 4) Build an online resource / engage a community

Guided by a 5-year plan with 99 specific deliverables.

**Solving important problems and  
advancing the science of electronics.**

# Tools

## Model and Analysis Prototyping Platform



Led by Jaijeet Roychowdhury, U.C. Berkeley



# Compact Circuit Models

Transistors (logic, RF, power)

Memory and memristors

Sensors (bio, environ)

Passives

...

MEMS/NEMS

Energy Generation

Optics / Photonics / OE

Spintronic/Magnetic



**44 models**

**20,000+ downloads**

**Open source license**

**Standard release**

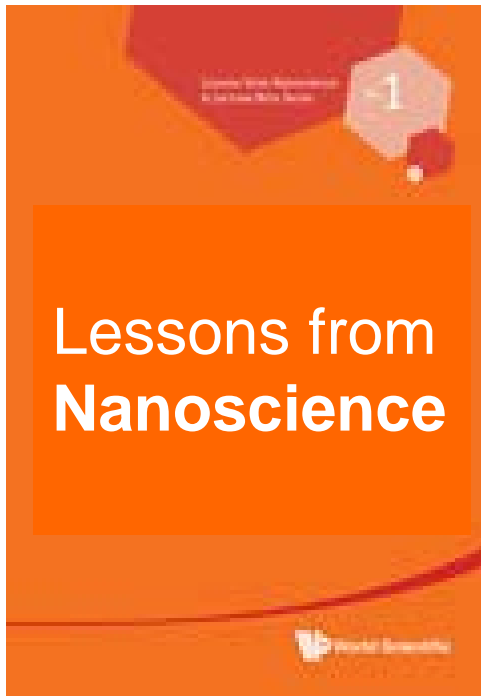
**package**

**self-publishing**

**expert curation**

Forward looking – with connections to industry

# NEEDS Education



“a forum for new approaches to evolve into the textbooks of tomorrow.”

The image is a screenshot of the nanoHUB.org website. The page features a navigation bar with "HOME", "COURSES", "FAQS", "FOR INSTRUCTORS", and "ABOUT". A quote from a nanoHUB-U student reads: "Teaching was so awesome it has inspired me to become a nano scientist". Below this is a photo of a man in a blue shirt. A section titled "LATEST ONLINE COURSES" lists several courses with their respective professors and dates. At the bottom, a "Welcome to nanoHUB-U" banner includes the text: "Translating disciplines with short courses accessible to students in any branch of science or engineering. Cutting-edge topics distilled into short lectures with success, homework, and practice exams." Below the banner are five yellow circles containing statistics: 27 courses, 75,000 learners, 1100 universities, 167 companies, and 151 countries. The edX logo is also present.

[www.nanoHUB.org/u](http://www.nanoHUB.org/u)

# Education for a new era

grand challenges in  
technology



May 9, 2017  
Forum on Graduate Education

[https://nanohub.org/groups/needs/  
grad\\_ed\\_forum\\_2017](https://nanohub.org/groups/needs/grad_ed_forum_2017)

“technology maestros”

# About NEEDS

POWERED BY [nanoHUB.org](http://nanoHUB.org) Login Register **Join Group** Help!

**NEEDS** NANO-ENGINEERED ELECTRONIC DEVICE SIMULATION NODE

NEEDS HOME **ABOUT US** RESOURCES CONTACT US NEEDS TEAM

## Nano-Engineered Electronic Device Simulation Node

*NEEDS has a vision for a new era of electronics that couples the power of billion-transistor CMOS technology with the new capabilities of emerging nano-devices and a charter to create high-quality models and a complete development environment that enables a community of compact model developers.*

*NEEDS Team: Purdue, MIT, U.C. Berkeley, and Stanford.*

[needs.nanoHUB.org](http://needs.nanoHUB.org)

- New compact model:** the Berkeley memristor model
- New tool:** MAPP 2.0
- New seminar:** "Probabilistic computing with nanomagnets, S. Datta
- New course:** Biological design principals

[More...](#)

### Models

COMPACT MODELS

SPICE-compatible  
Verilog-A format  
supporting resources

### Tools

COMPACT MODELS:  
TOOLS

Tools for developers  
including **MAPP** & **VALint**.

### Training

COMPACT MODELS:  
RESOURCES FOR DEVELOPERS

Seminars and tutorials for  
developing and publishing  
compact models

### Science Systems

NANOSCIENCE TO SYSTEMS

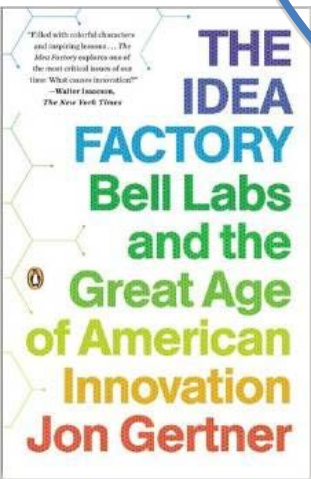
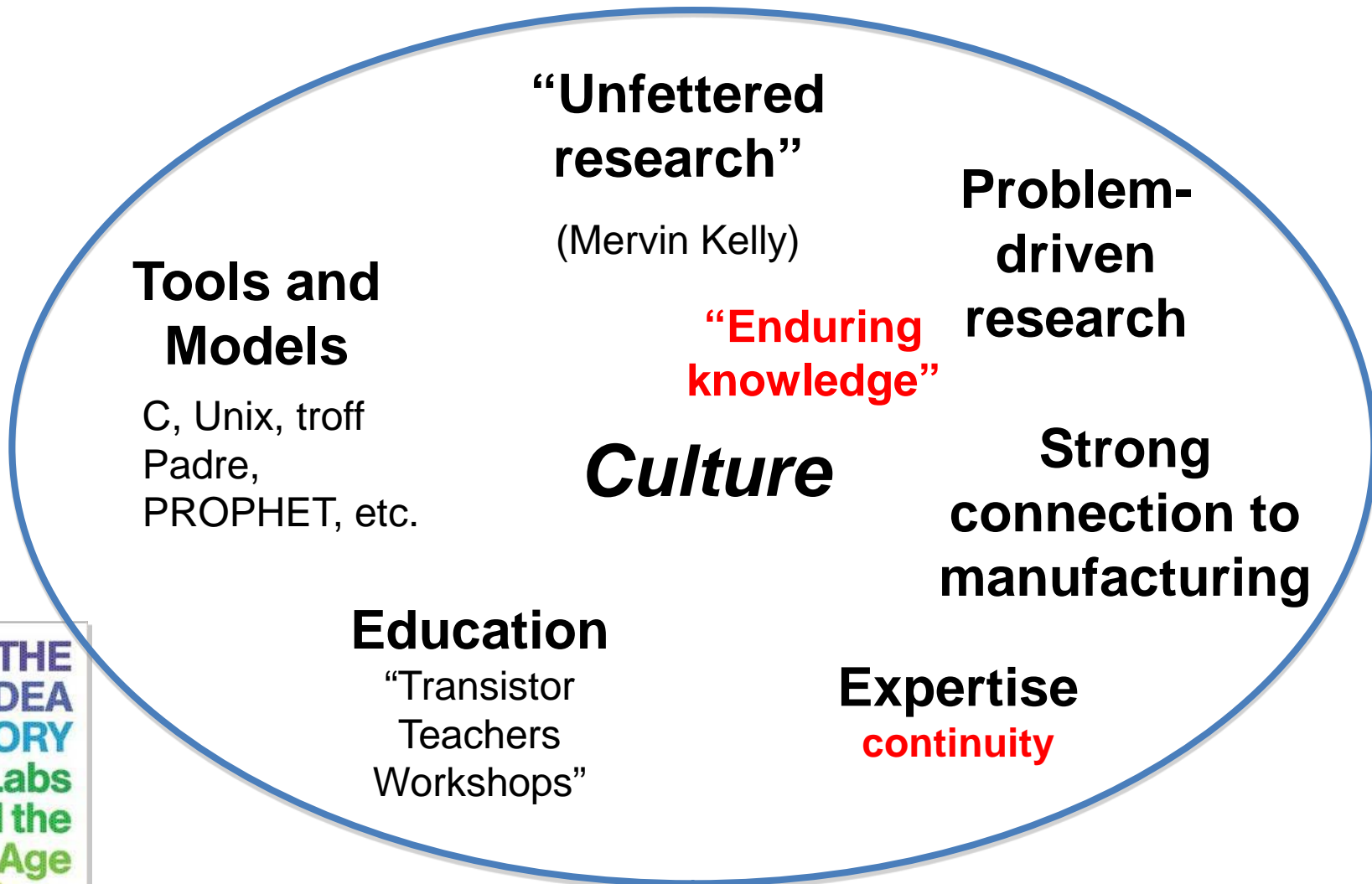
Physically-detailed simulations  
system level tools

### Education

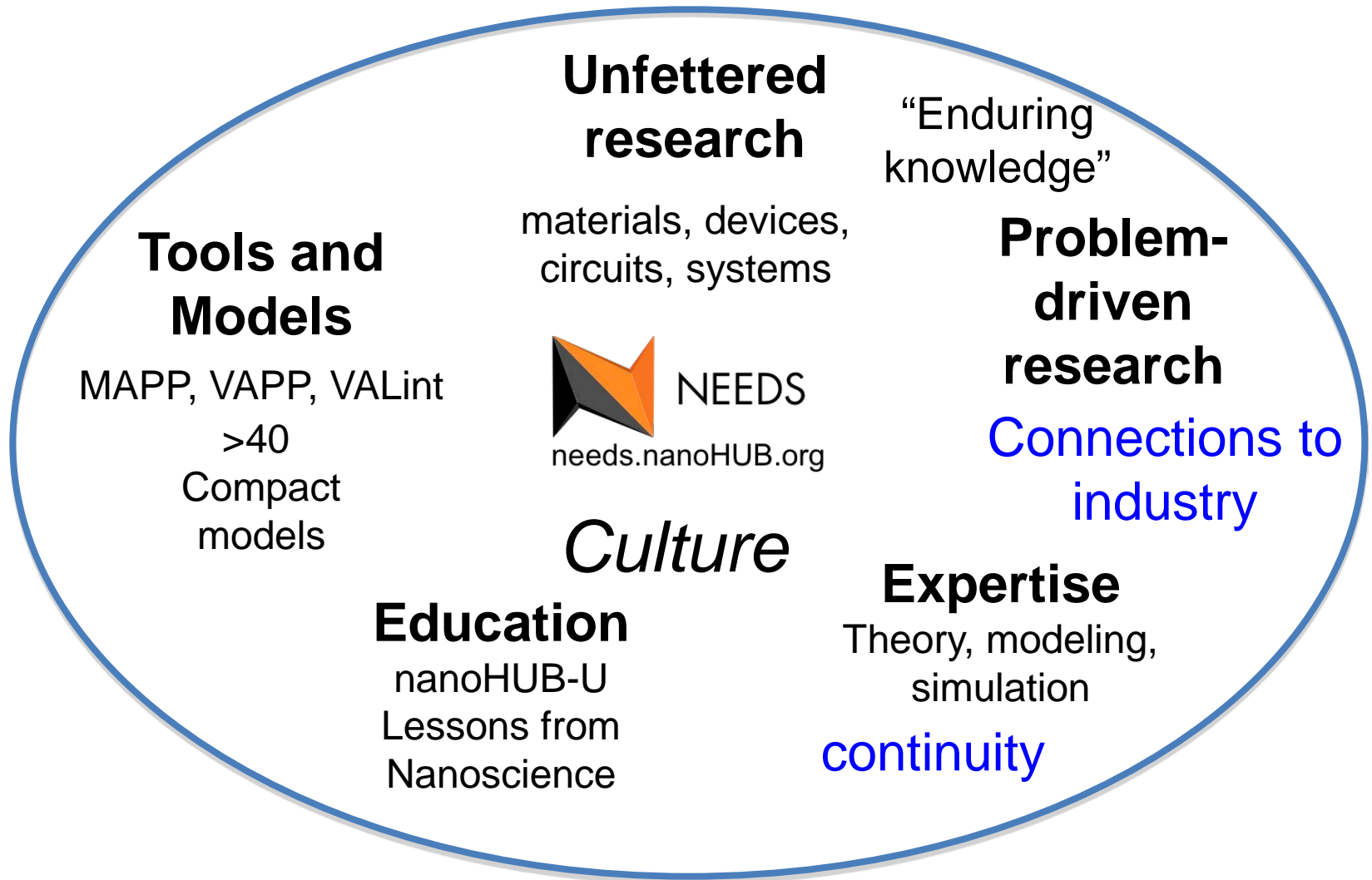
NANOSCIENCE: SEMINARS,  
COURSES, ETC.

NEEDS Seminars, workshops,  
nanoHUB-U and more

# Bell Labs



# A platform to support 21<sup>st</sup> Century Electronics



# About today's program



Eric Pop  
Stanford University