Democratizing Engineering:

"Our Carpe Diem Moment"

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My Message:

- Modify the conversation
- Practice what's known
- Seize the opportunity
- Change the world

The Conversation…

Engineer...

Engineer...

comes from a Latin word meaning cleverness (ingenium)

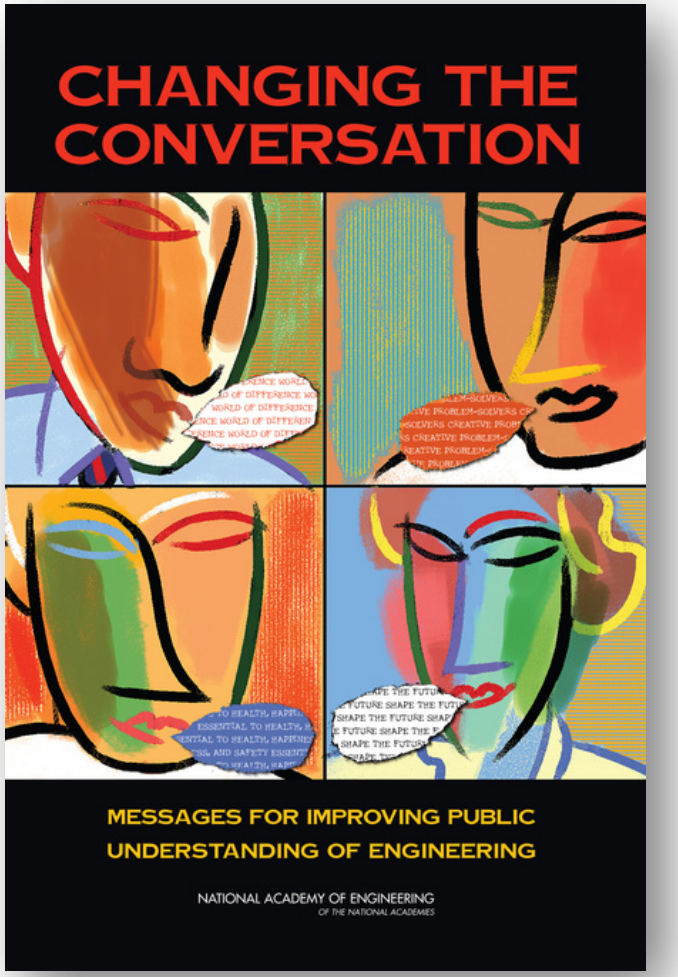
Engineering

- Improves the quality of life
- Enables people to accomplish more, with less...
  - Effort
  - Consumption of resources, environmental impact
  - Energy
  - Cost
- Makes the world a better place

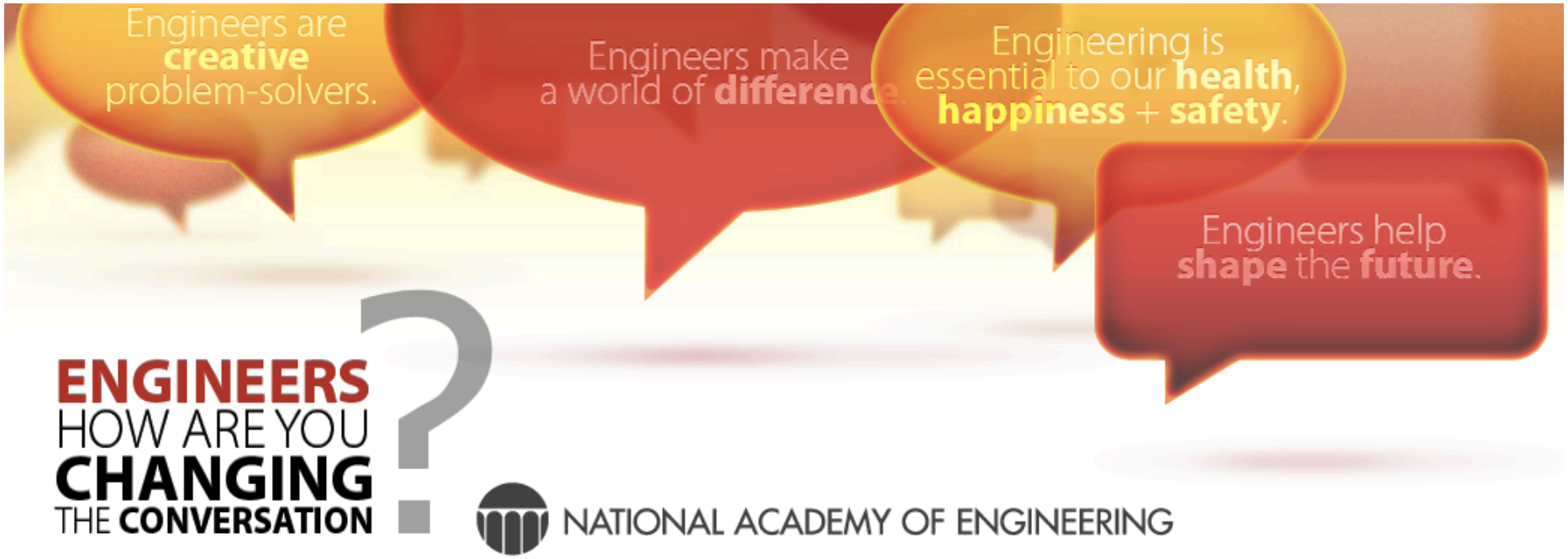
Let’s take a vow...


Engineering is Hard

Need to Change the Message



http://www.engineeringmessages.org



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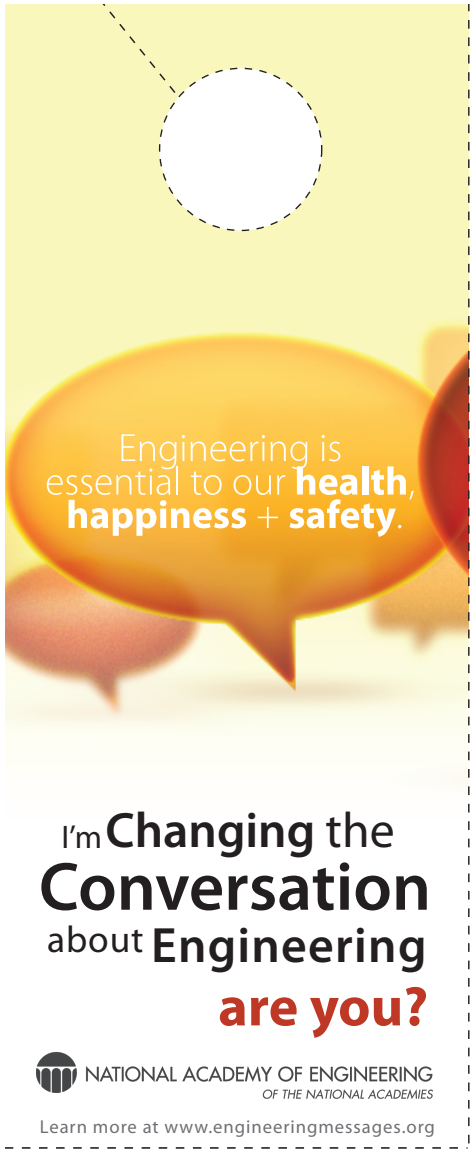


Instead...

Engineering is Exciting!

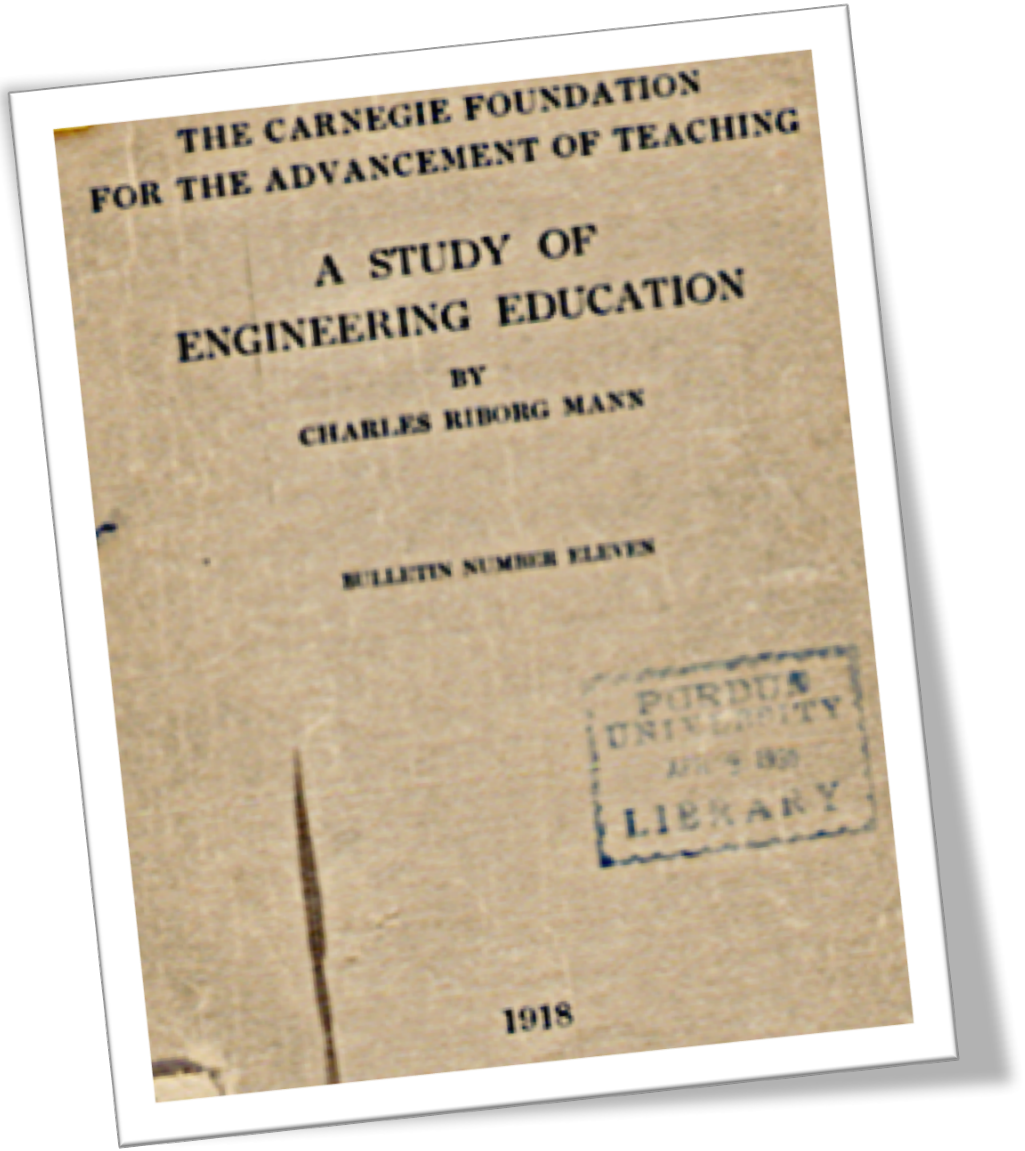
Practice what's known…

100 years ago…

1907 – Joint Committee on Engineering Education *(Cleveland)*

- American Society of Civil Engineers
- American Society of Mechanical Engineers
- American Institute of Electrical Engineers
- American Chemical Society
- American Institute of Chemical Engineers
- American Institute of Mining Engineers
- Society for the Promotion of Engineering Education (now ASEE)

The Mann Report (1918)



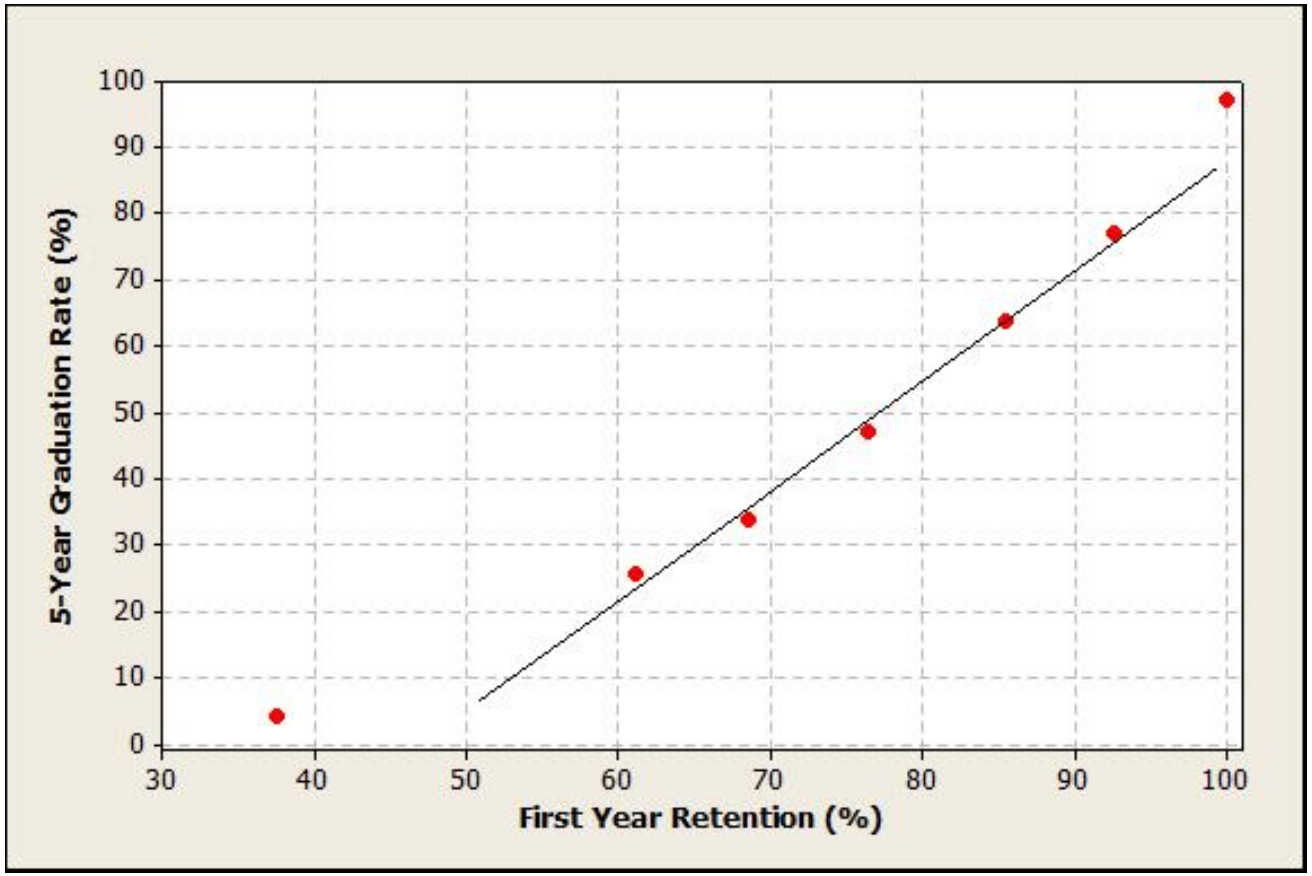
Graduation Rate (1918)

60%

Graduation Rate (2016 – average 5 year)

50%

5 Year Graduation Rate Data (2016)



(sample of 150 schools)

DataBytes. (2016, February) In Grose, T. (Ed) *ASEE Connections*, Washington DC:ASEE.

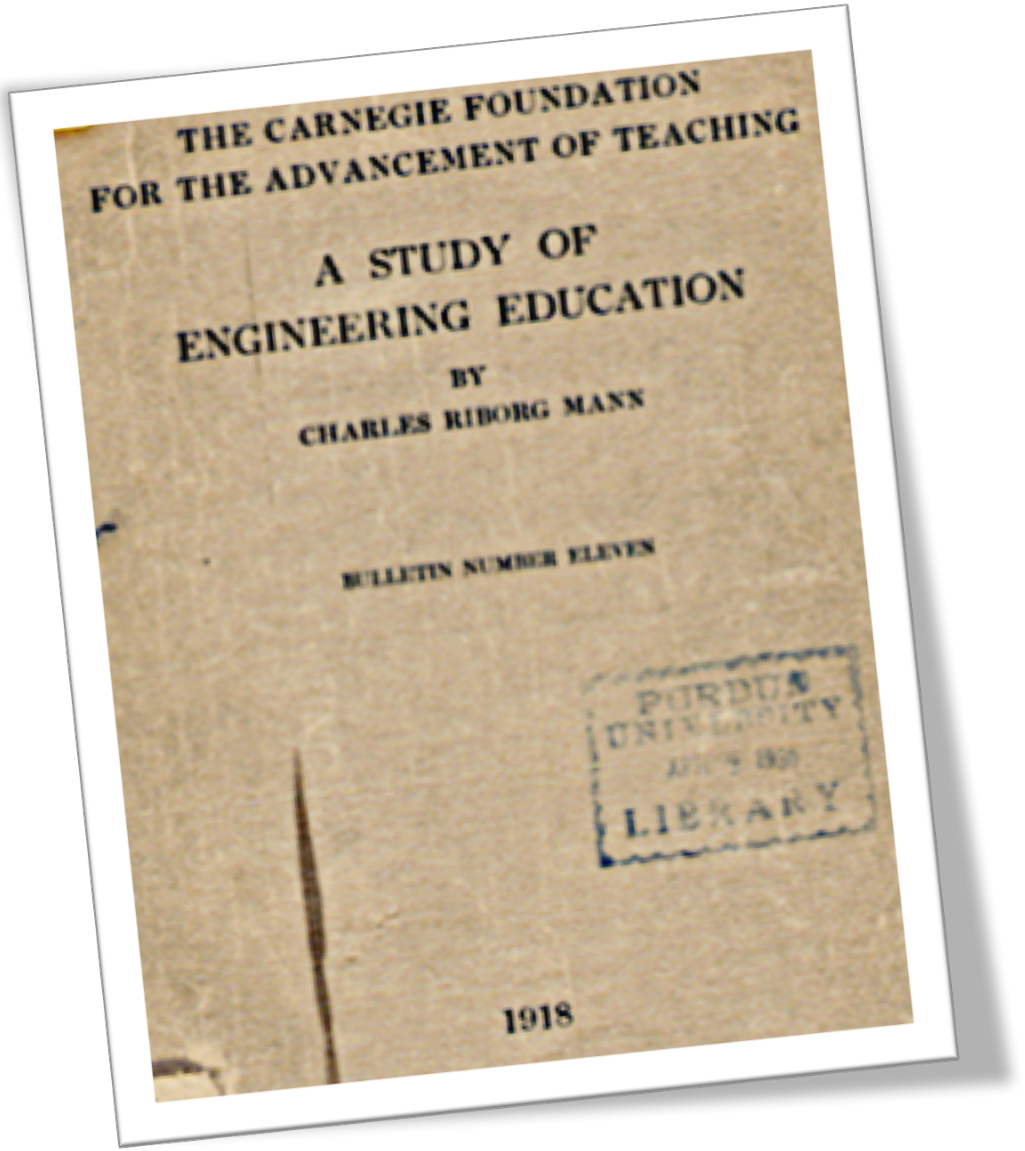
5 Year Graduation Rate in 2016 (%)

$$= 1.676 \times (1^{st} \text{ Year Retention Rate}) - 79.22$$

DataBytes. (2016, February) In Grose, T. (Ed) *ASEE Connections*, Washington DC: ASEE.

The Mann Report (1918)

"There probably never was a time when the minds of teachers were so intently alive and receptive to rapid changes, as at the present moment."



Over the past 50 years...

- Numerous reports/studies/projects have identified issues and concerns about declines in STEM comprehension, workforce capabilities, and national competitiveness – *many have also suggested solutions...*
  - National Academies ~ 26
  - ASEE ~ 17

For example . . .

National Challenges

- U.S. will not have enough qualified STEM-trained workers to fill available jobs
- Lack of technical expertise will jeopardize the power grid, national security and defense
- We will not be able to successfully innovate and compete globally without more engineers

Key Engineering Issue

- Students need ample hands-on opportunities to grasp the “big ideas” in engineering; yet they don’t have the same *physical intuition* of prior generations
- Students need time to explore/play with the tools and need further *tinkering opportunities* to support their design courses…

We Know: *Why Students Leave*

- Lack of role models and inclusive culture – *particularly for women and underrepresented minority faculty*
- Poor teaching and advising
- Poor performance in the first math courses
- Lack of connection between what is studied and exciting engineering practice

We Know: *There's a Dichotomy*

- In school, problems almost always are clearly defined, confined to a single discipline, and typically have one right answer

- In the workplace, problems are usually ill-defined, multi-disciplinary, and have several possible answers *(none of which are perfect)*

Creativity Definition (D. Pink)

Topic	Industry	Academia
Problem identification or articulation	**1**	**9**
Ability to identify patterns of behavior or new combination of actions	2	3
Integration of knowledge across different disciplines	3	2
Ability to originate new ideas	4	6
Comfort with notion of “no right answer”	5	11
Fundamental curiosity	6	10
Originality and inventiveness in work	7	4
Problem solving	**8**	**1**
Ability to take risks	9	8
Tolerance of ambiguity	10	7
Ability to communicate new ideas to others	11	5

We Know: *from Research*

- Learning is highly dependent on **prior knowledge**
- **Motivation** is critical – it determines, directs, and sustains what students do
- How students **organize knowledge** influences how they learn and apply what they know

We Know: *from Research*

- **Climate** *(intellectual, social, and emotional)* has significant impact on student perception and outcomes
- On average, online course-taking **reduced** student learning (1/4 to 1/3 – Oct. 2015 DeVry study)
- Active learning **is better than** passive methods, hands-down...**period**.

We Know: *from Research*

- Does this make sense?
  Based on experience
- Does it have meaning?
  Material relevant to the learner
- Meaning is more significant for longer-term storage
- Students will remember more if provided less at any given time
  (average capacity of working memory is 7 chunks)

We Know: *from Students* *(ASEE TUEE workshop)*

- Allow faculty members to teach subjects they're passionate about or really skilled at teaching
- Connect the applications to engineering in first-year math and science courses – calculus, physics, and chemistry
- Need to help professors learn how to teach

We need to:

- Enable students to better acquire T-skills
- Diversify pathways to, and through, engineering education
- Fill gaps in workforce expertise (e.g., power)
- Understand how to scale engineering education innovations and do it

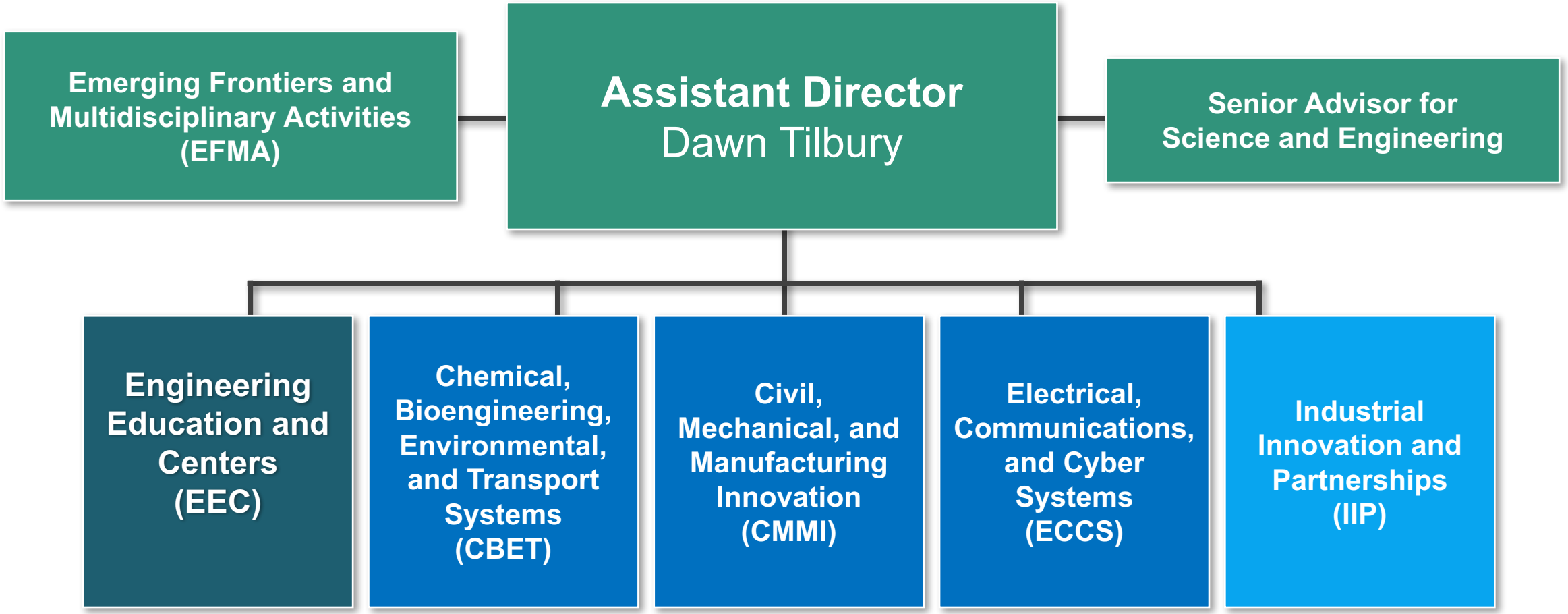
The opportunity…

Why we're here…

Engage Academia, Societies, Industry and Government Representatives to:

Increase collaboration between the engineering academic and industry community in the Southeast US

NSF Directorate for Engineering



Directorate for Engineering – Programs

Fundamental Research

EFMA

- Emerging Frontiers in Research and Innovation (EFRI)
- Multi-disciplinary education programs
- Research facilities

CBET

- Chemical Process Systems
- Engineering Biology and Health
- Environmental Engineering and Sustainability
- Transport Phenomena`

CMMI

- Advanced Manufacturing
- Mechanics and Engineering Materials
- Resilient and Sustainable Infrastructure
- Operations, Design, and Dynamic Systems

ECCS

- Electronics, Photonics, and Magnetic Devices
- Communications, Circuits, and Sensing Systems
- Energy, Power, Control, and Networks

EEC

- Centers and Networks
- Engineering Education
- Broadening Participation in Engineering
- Engineering Workforce Development

Translational Research

IIP

- Industry University Partnerships
- Small Business Innovation Research
- Small Business Technology Transfer
- Entrepreneurial Training

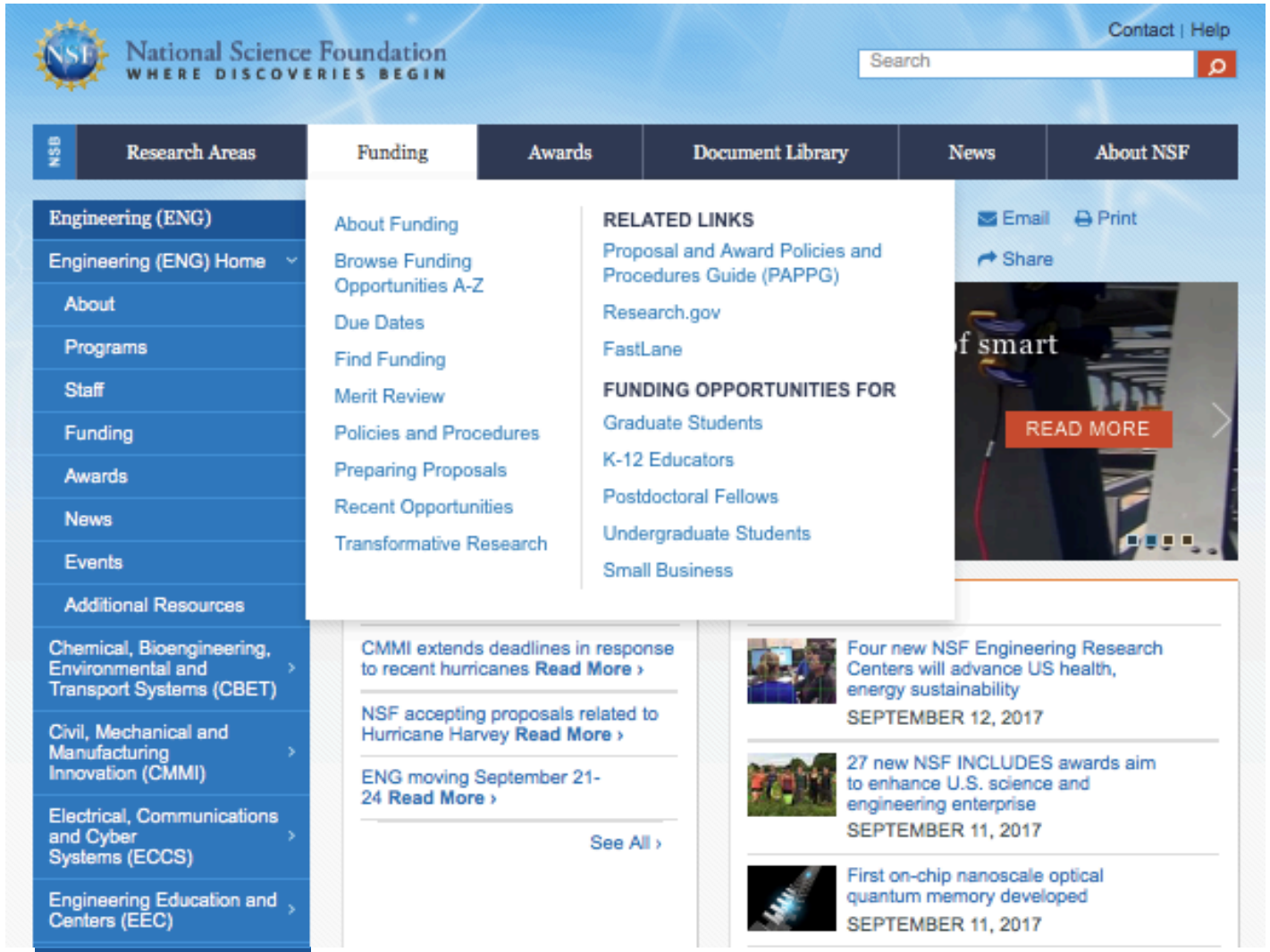
Current Engineering Initiatives

- Brain Research through Advancing Innovative Neurotechnologies (BRAIN)
- Advanced Manufacturing Partnership (AMP)
- Clean Energy
- National Robotics Initiative (NRI)
- National Strategic Computing Initiative (NSCI)
- Strategy for American Innovation

FY2017 Administration Priorities

- Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS)
- Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS)
- Risk and Resilience
- Understanding the Brain
- Inclusion across the Nation of Communities of Learners that have been Underrepresented for Discoverers in Engineering and Science (INCLUDES)
- Innovation Corps (I-Corps™)

FY2017 NSF-wide Priorities

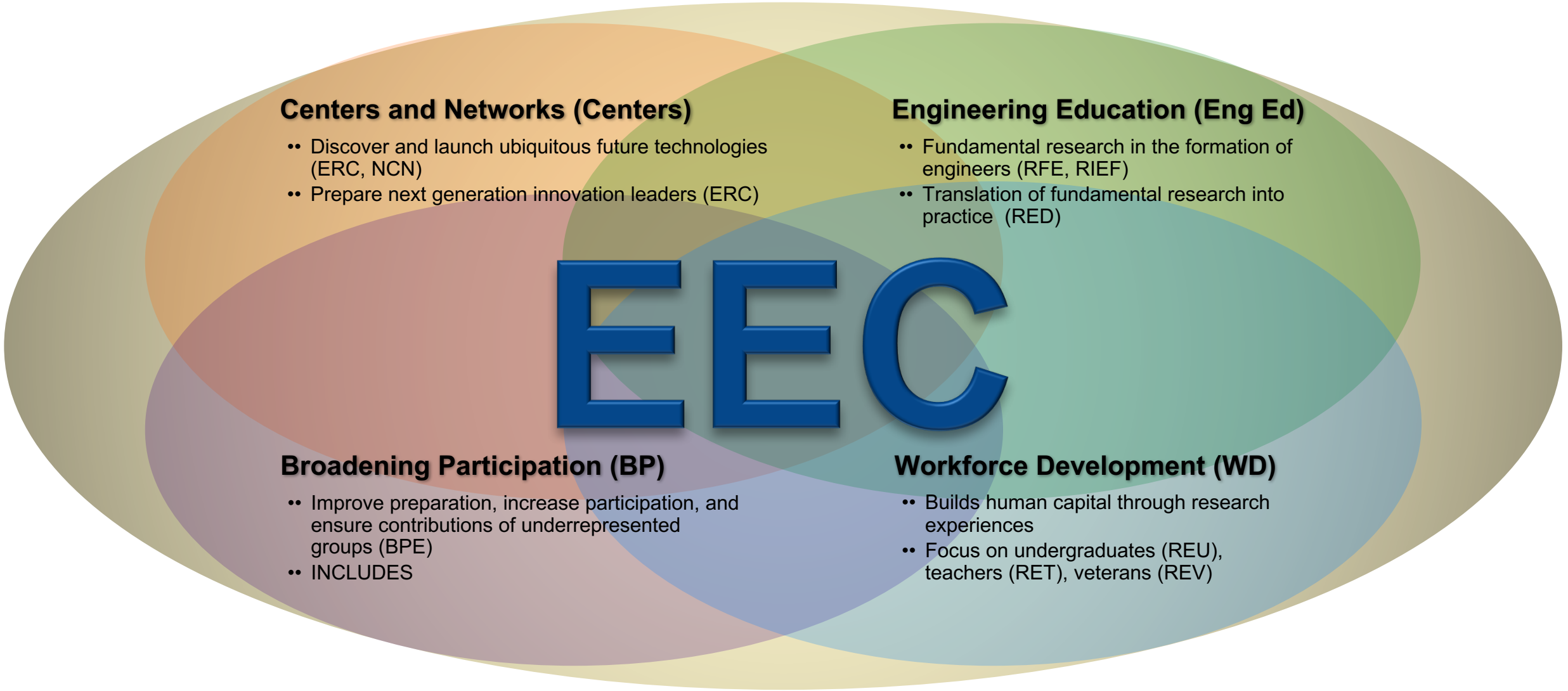


Google: **NSF ENG**

Engineering by the Numbers

Activity	FY 2014	FY 2015	FY 2016
Number of Proposals	11,933	12,307	12,574
Number of Awards	2,261	2,486	2,502
Funding Rate	18.9%	20.2%	19.9%

- Estimated number of researchers and students supported: **23,350**
- Centers supported (Many Collaborative with Other Directorates):
  - 14 Engineering Research Centers (ERCs)
  - 3 Science and Technology Centers (STCs)
  - 77 Industry University Cooperative Research Centers (IUCRCs)
  - 3 Research Facility Networks



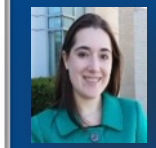
Investing to address societal grand challenges, promote innovation, and benefit society

EEC Organization

Elliot Douglas
Program Director
(Eng Ed)

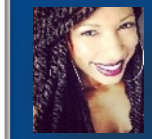
Mary Poats
Program Director
(WD)

Paige Smith
Program Director
(BP)



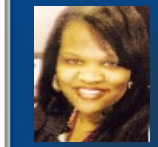
Amelia Greer
Science Analyst

Don Millard
Acting Division
Director/Deputy
Division Director

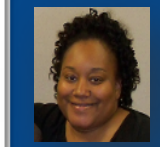


Alisha Williams
Program Support
Manager

Marshall Horner
Operations
Specialist

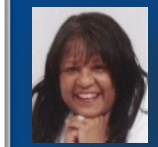


Tammie Jennings
Program
Specialist



LaTanya Sanders-Peak
Program
Specialist

Shalika Walton
Program
Specialist



Susan Watson
Program
Specialist

Deborah Jackson
Program Director
(ERC)

Carmiña Londoño
Program Director
(ERC)

Eduardo Misawa
Program Director
(ERC/NCN)

Junhong Chen
Program Director
(ERC)

Erick Jones
Program Director
(ERC)

Patricia Simmons
AAAS Fellow

Centers and Networks
(Centers)

EEC

Centers and Networks (Centers) – FY16: $60,485,455

- Discover and launch ubiquitous future technologies
- Prepare next generation innovation leaders

ERC Program

Launched in 1984 - based largely on guidelines proposed by the NAE (1983)

Goals:

- Strengthen the competitiveness of the U.S.
- Translate discovery to innovative products
- Prepare next generation of technological leaders

Distinguishing Features of an ERC

- **Engineering <u>systems</u>** focus:

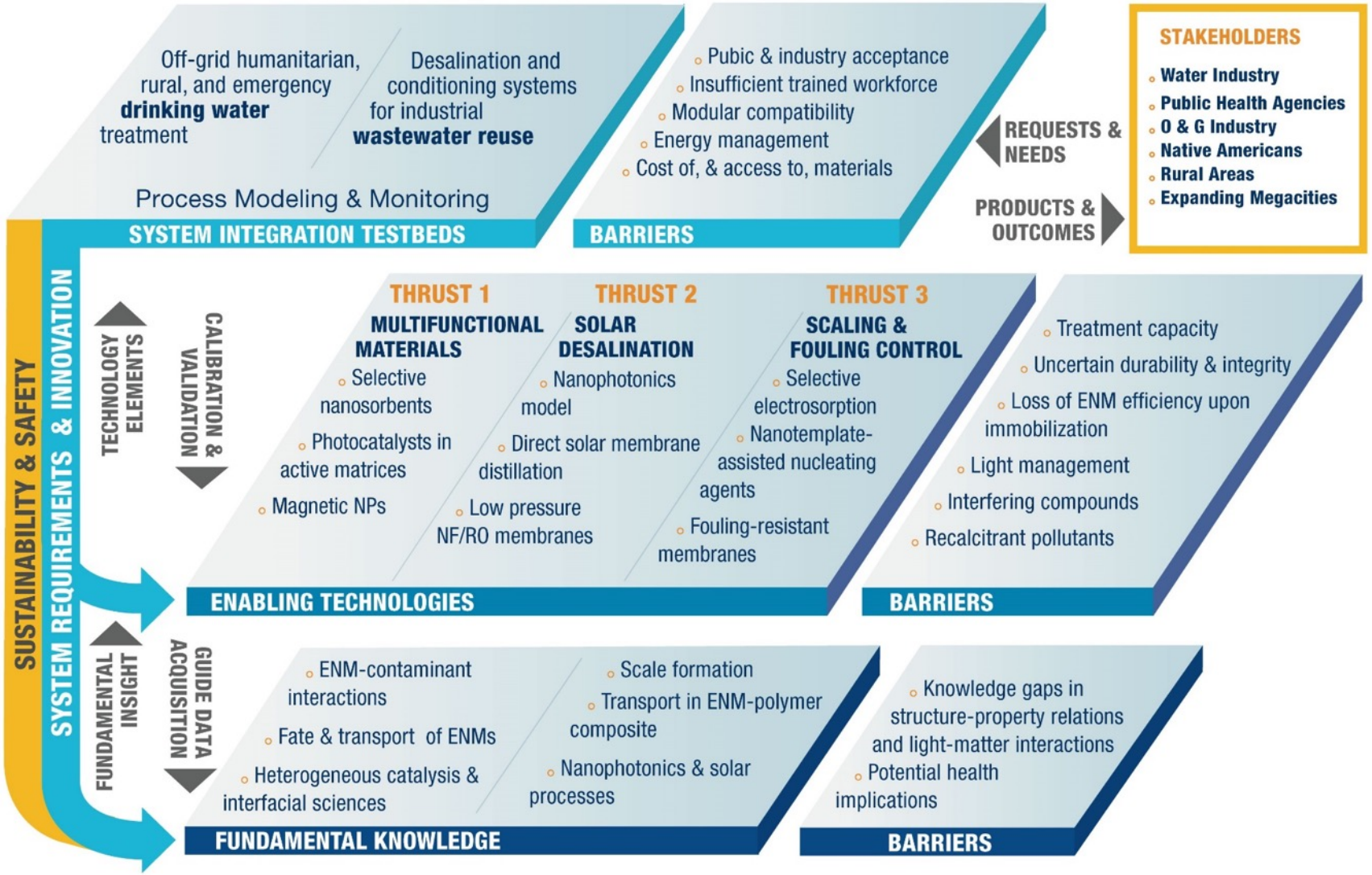
  Spans the gamut from fundamental research to proof-of-concept testbeds

- A 10-year strategic plan to overcome fundamental technical barriers; w/NSF funding: ~ $4M/year

ERC 3-Plane Diagram Example

Courtesy of:

Nanotechnology-Enabled Water Treatment (NEWT) ERC



Key Questions: (last competition)

1. What is the compelling new idea and how does it relate to national needs?
2. Why is a center necessary to tackle the idea?
3. How will the ERC infrastructure integrate and implement research, workforce development and innovation ecosystem development efforts to achieve its vision?

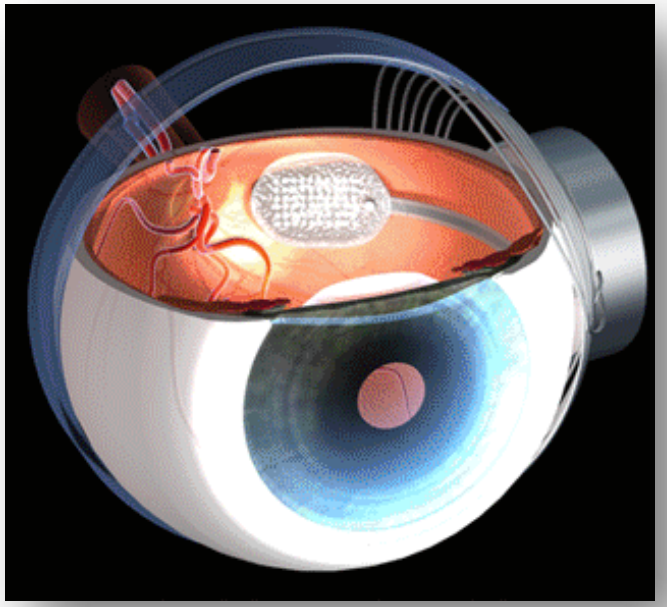
ERC Program

- NSF has supported 67 ERCs
- 82% "Graduated" ERCs were self-sustaining (as of 2012)
- Degrees awarded (to date):
  - 4,122 B.S.
  - 4,022 M.S.
  - 4,562 Ph.D.

ERC Example – “BMES”

Biomimetic **M**icro**E**lectronic **S**ystems Center – an external camera sends images to a microelectronic implant in the eye, which stimulates the retina of a blind person to provide a sense of vision - FDA approval was granted in 2013

Image Credit:
BMES ERC Website
(http://tinyurl.com/jffrsd6)




Four new NSF Engineering Research Centers

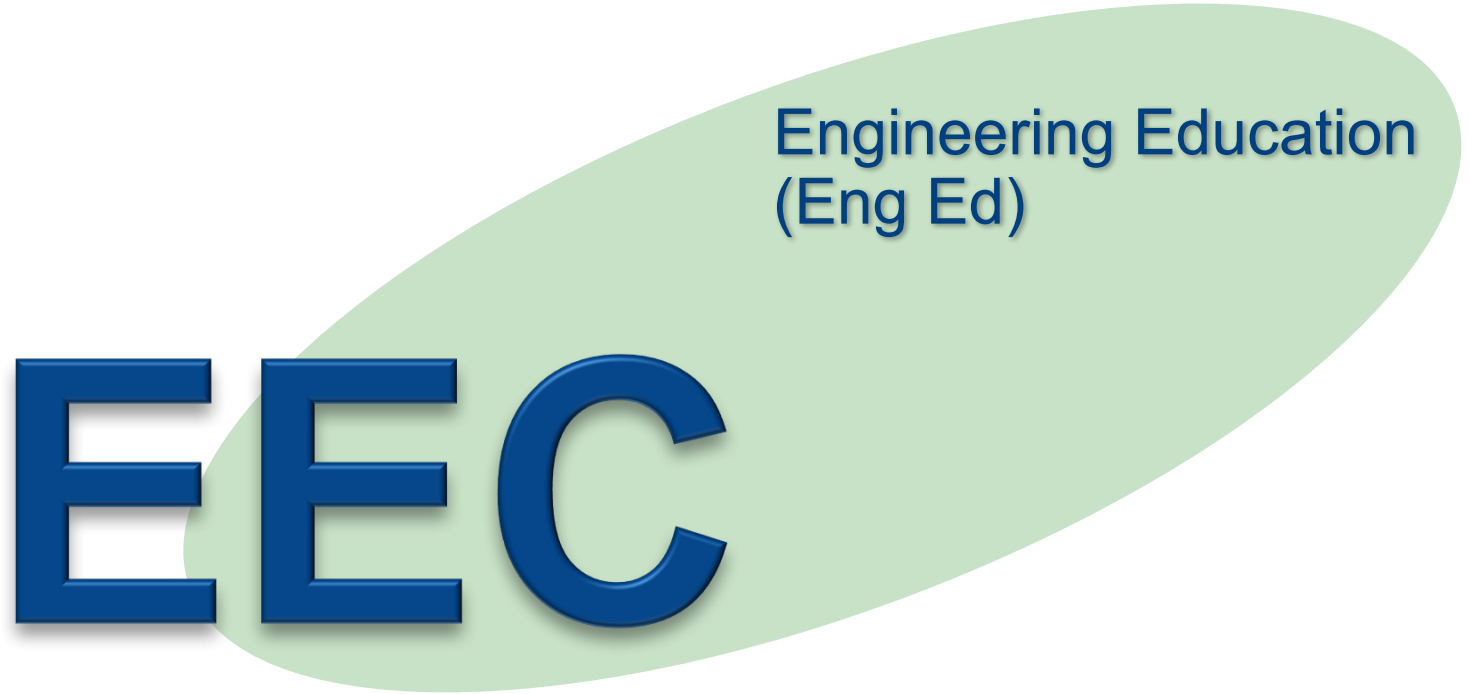
A New Vision for Center-Based Engineering Research

Committee on a Vision for the Future of Center-Based Multidisciplinary Engineering Research
National Materials and Manufacturing Board
Division on Engineering and Physical Sciences
National Academy of Engineering

http://www.nap.edu/24767

May 2017

Image: *National Academies Press, Copyright 2017, National Academy of Sciences*



Engineering Education (Eng Ed) – FY16: $13,534,596

- Fundamental research in the formation of engineers
- Translation of fundamental research into practice

Professional Formation of Engineers

- Overarching theme for EEC's Engineering Education programs
- Shift emphasis from how students learn engineering to how engineers are formed
- An understanding of how to enact change
- Increased focus on the effectiveness of pedagogy
- Focus on inclusion (climate) vs. diversity (numbers)

Engineering Education

- Research in the Formation of Engineers (RFE)
  - Developing skills (technical and professional)
  - Exploring engineering-specific learning theories and frameworks
  - Diversifying pathways to and through engineering education
  - Understanding how to scale engineering education innovations

Engineering Education

- Research Initiation in Engineering Formation (RIEF)
  - Mentorship model to expand capacity for conducting engineering education research
  - Leverage and expand the education research knowledge base across an institution

Engineering Education

- REvolutionizing Engineering and Computer Science Departments (RED - ***no solicitation for FY18***)
  - Strong partnership with CISE and EHR
  - Project funding: ~ $2M, for up to 5 years
  - Implementation of research into practice
  - Focus on the middle years
  - “T Shaped” professional skills

FY18 Engineering Education Priorities

- Research the impact of engineering education research
  - How to translate knowledge into practice
  - Effective strategies for scaling
  - Role of networks and communities
- Diversify the pool of institutions and PIs submitting proposals
- Expand support of K-12, two-year college, graduate, career programs

Other Programs in Engineering Education

- Improving Undergraduate STEM Education: EHR, 17-590
- Advanced Technology Education, 17-568 (watch for new solicitation)
- NSF Scholarships in STEM, 16-540

Broadening Participation (BP) – FY16: $11,448,888

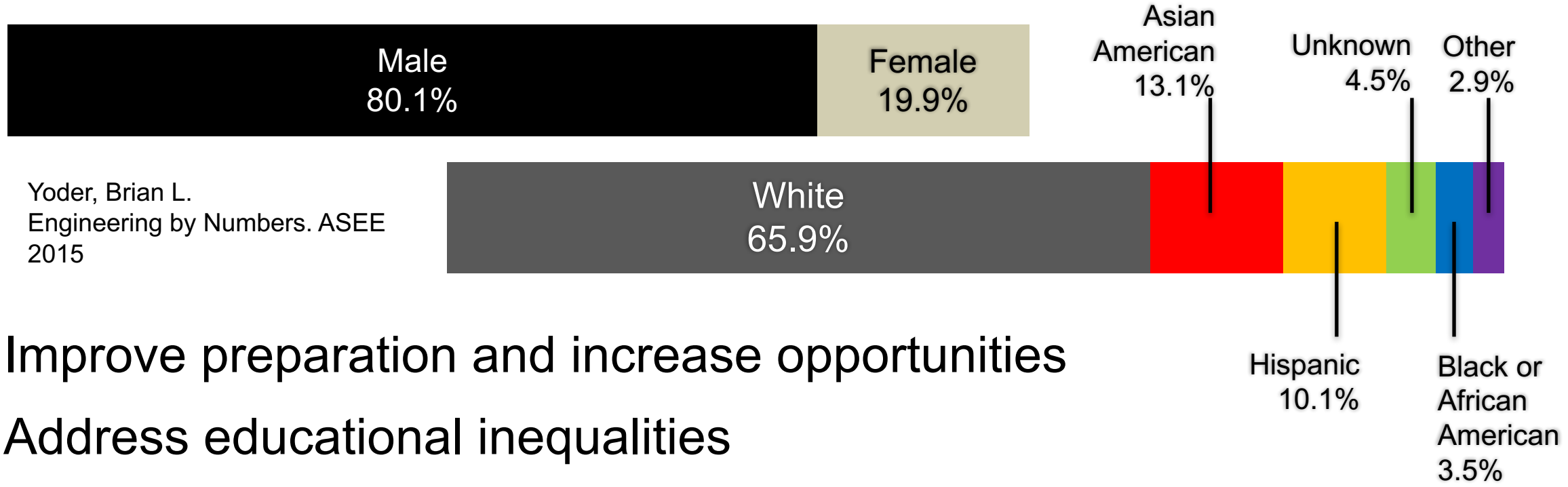
- Improve preparation, increase participation, and ensure contributions of underrepresented groups
- INCLUDES

Broadening Participation in Engineering

- Directorate-wide program to support the development of a diverse engineering workforce
- Supports research and demonstration projects that:
  - Contribute to the knowledge base of broadening participation in engineering (K - gray)
  - Diversify the entire engineering enterprise, including the professoriate
  - Focus on racial and ethnic minorities
- Focuses on 4P's: People, Programs, Places, Policies

BPE Challenges

- Increase interest and sustain participation in engineering across underrepresented demographic groups



Yoder, Brian L. Engineering by Numbers. ASEE 2015

- Improve preparation and increase opportunities
- Address educational inequalities
- Expand support systems and social networks

BPE Objectives

- Address educational inequalities (e.g., math preparation)
- Expand support systems and social networks
- Increase interest and sustain participation in engineering across underrepresented demographic groups

FY17 BPE Program Priorities

- Influence engineering organizations' culture – better understand barriers
- Increase faculty and institution engagement in BP (e.g., CAREER workshops, policy studies)
- Perform outreach to pivotal stakeholders/institutions
- Leverage INCLUDES – to develop engineering talent from all sectors and groups in our society

NSF INCLUDES

Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science

Credit: NSF/Stephen Voss

NSF INCLUDES is a comprehensive initiative to enhance U.S. leadership in science and engineering discovery and innovation by proactively seeking and effectively developing science, technology, engineering and mathematics (STEM) talent from all sectors and groups in our society.

By facilitating partnerships, communication and cooperation, NSF aims to build on and scale up what works in broadening participation programs to reach underserved populations nationwide.

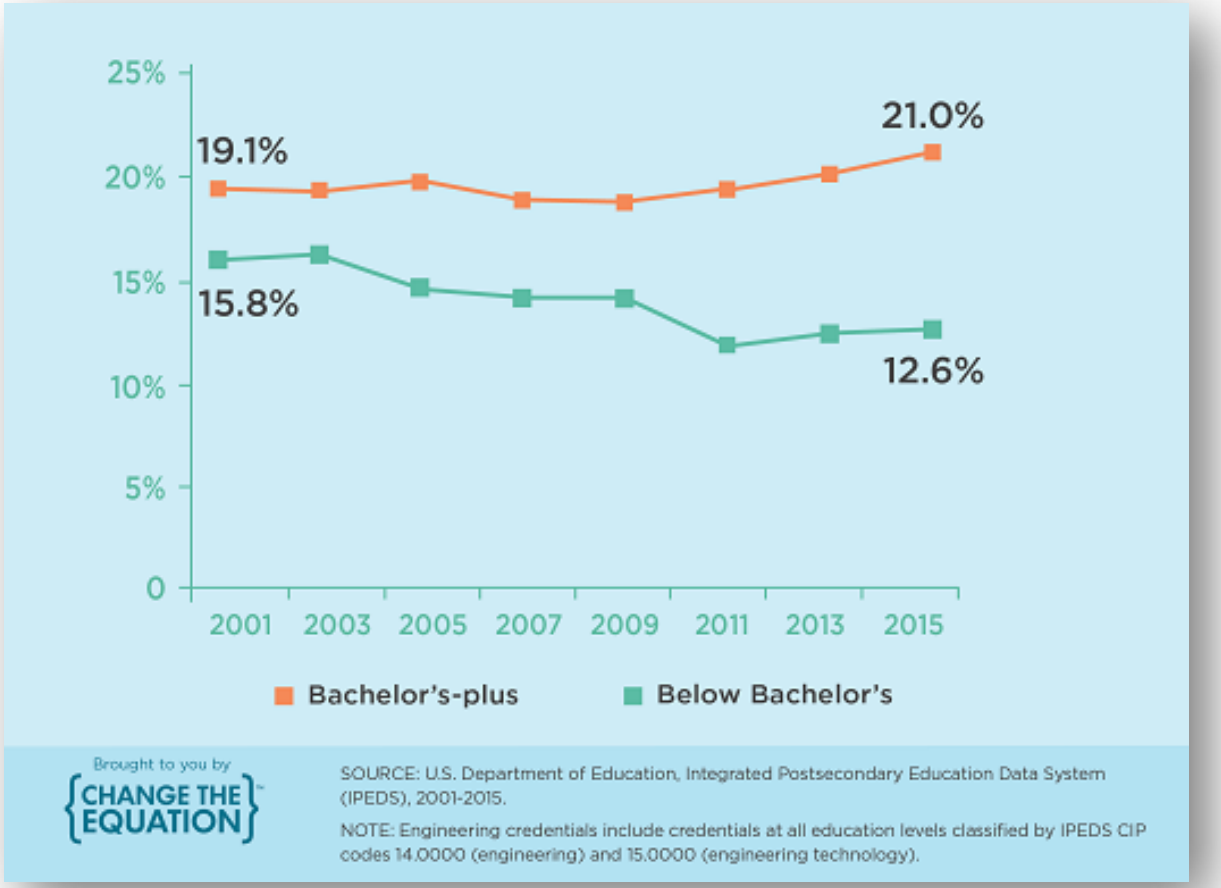
NSF INCLUDES Components: a multi-stage, multi-year initiative

- Design and Development Launch Pilots
- Coordination Hub
- "On-ramp" DCL opportunities
  - EAGER
  - Supplements
  - Workshops
- Alliances

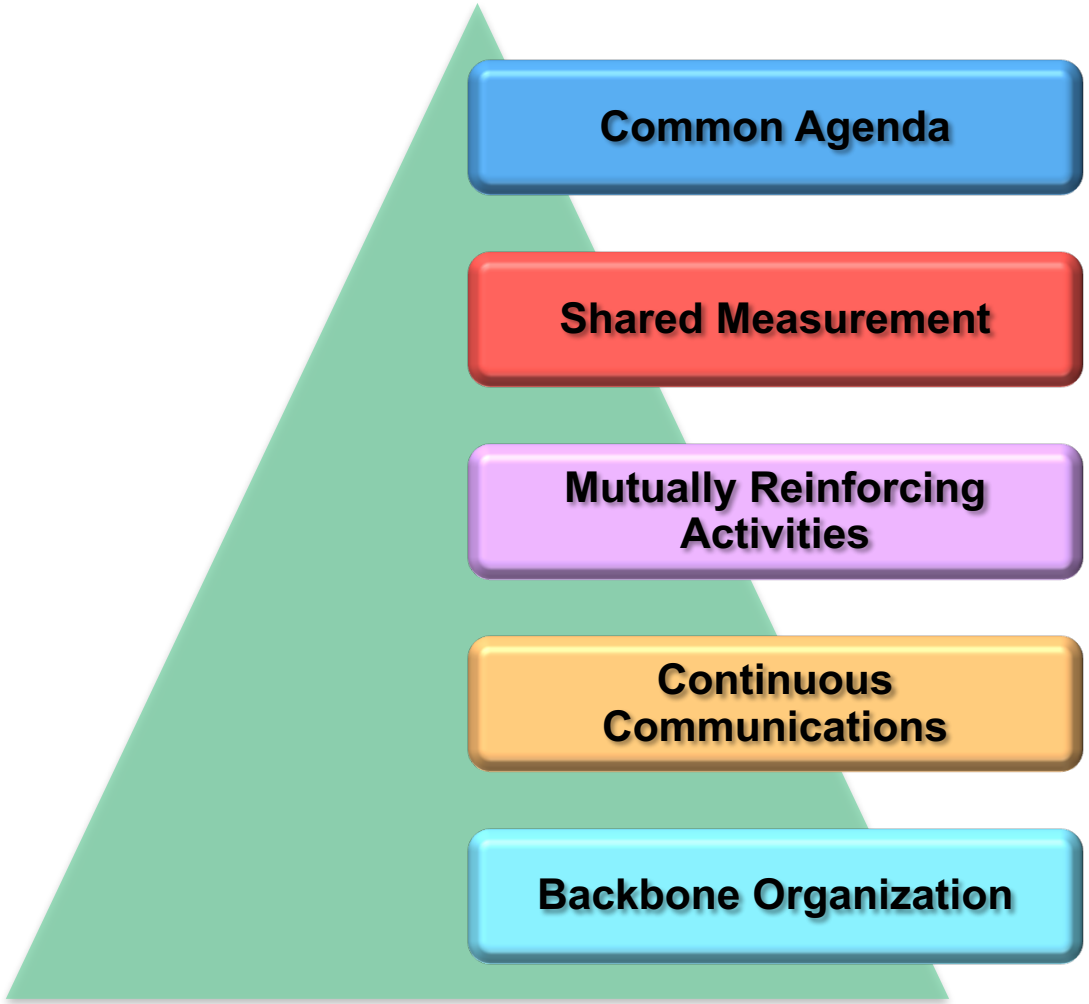
A Challenge for Engineering:

Double the % of women in Engineering

(20% → 40% in 5-10yrs)



A Potential Strategy



- *Develop a technology-relevant, best-practices-based framework/approach to engineering education*

- *Collect learning data using common tools (e.g., TDOP)*
- *Shared accountability across courses, depts., schools*

- *Coordinated national curriculum/framework*
- *Regional/National industrial collaborations*

- *Professor training, web collaboration, mentoring*
- *Co-teaching, shared monitoring*

- *National Engineering Education Network*
- *Communication, data acquisition/integration/analysis*

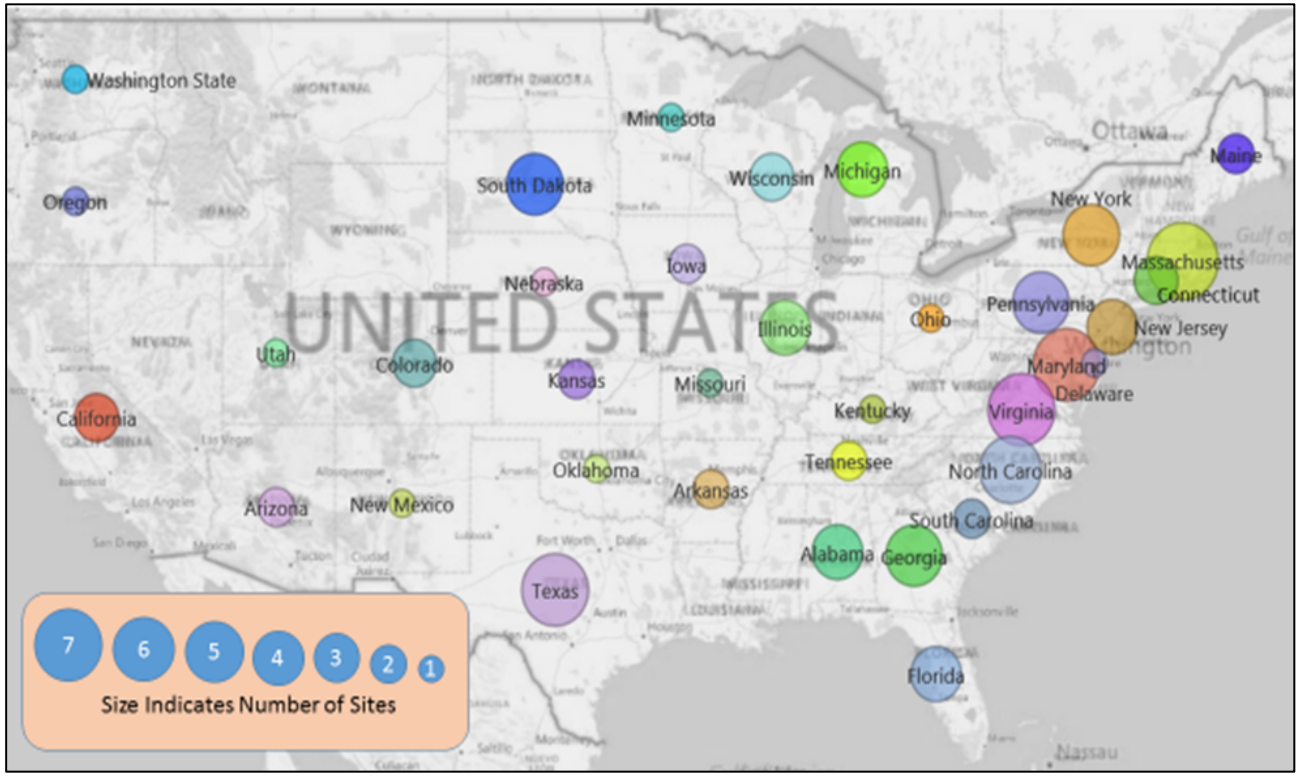
Source: www.collaborationforimpact.com

Workforce Development (WD) – FY16: $16,936,228

- Builds human capital through authentic research experiences
- Focus on undergraduates, teachers, veterans

Research Experience for Undergraduates Sites (REU)

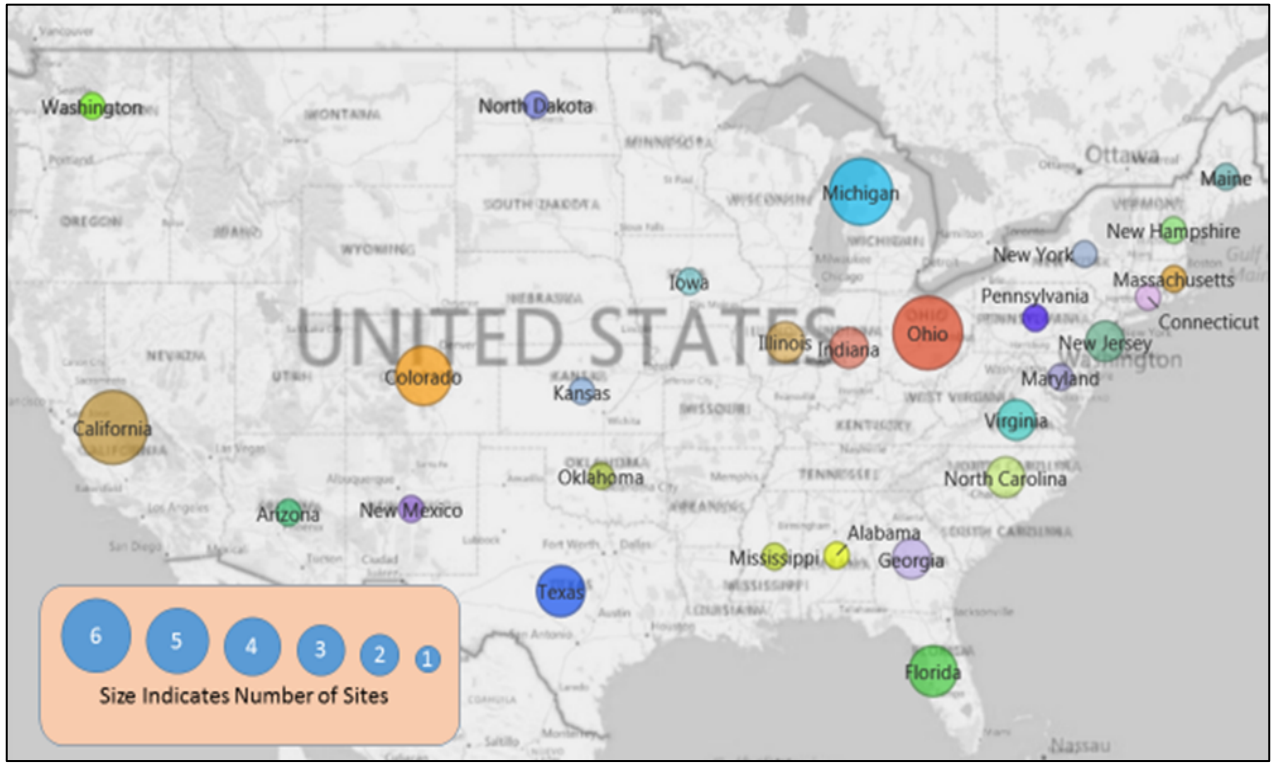
- Supports participation of undergraduate students in all research areas supported by ENG
- Encourages pursuit of graduate education
- Promotes integration of research and education
- Develops a diverse and competitive workforce



- 125 active sites in 35 states
- Over 1,000 students per year

Research Experience for Teachers Sites (RET)

- Supports pre-service, in-service K-12 STEM teachers and community college faculty in ENG research
- Participants translate research experiences into classroom activities
- Facilitates professional development
- Includes industrial partners/advisors to address industry's workforce needs
- Provides instructional opportunities – via grad student mentorship, involvement in K-12 classroom activities



- ➢ 40 active ENG sites in 25 states
- ➢ ~ 400 STEM teachers/community college faculty per year

AP in Engineering Exploration

Workshops (Fall 2017)

- Design process
- Curriculum review
- NGSS
- 21st Century Skills
- Teacher preparation/professional development

Pilot project to explore potential

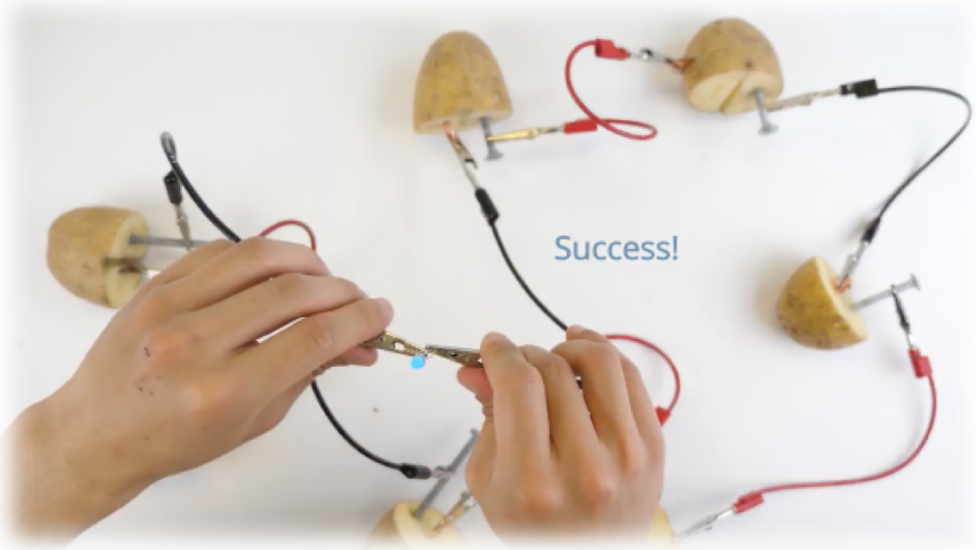
TEACHENGINEERING
curriculum for k-12 teachers

design thinking. the power to create.

- Engages students in real-world engineering
- Standards-aligned content (NGSS, Common Core Math, ITEEA, etc.)
- Hands-on, K-12 engineering curriculum - *designed for teachers*
- **1,645** high-quality, free engineering lessons & activities
- Approximately **3 million** unique users in 2016
- Sustainability: authors from **52 entities** (most from NSF projects)

New in 2017! ★ **TE content highlighted by NAE's LinkEngineering** – connecting K-12 teachers to *share their TeachEngineering experiences* ★ Maker Challenges recently launched ★ Partnering with SparkFun on *Maker* ★ Adding "Amazon-like" recommender service

TeachEngineering.org



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Student Ambassadors

PennState College of Engineering

Create. Connect. Change.

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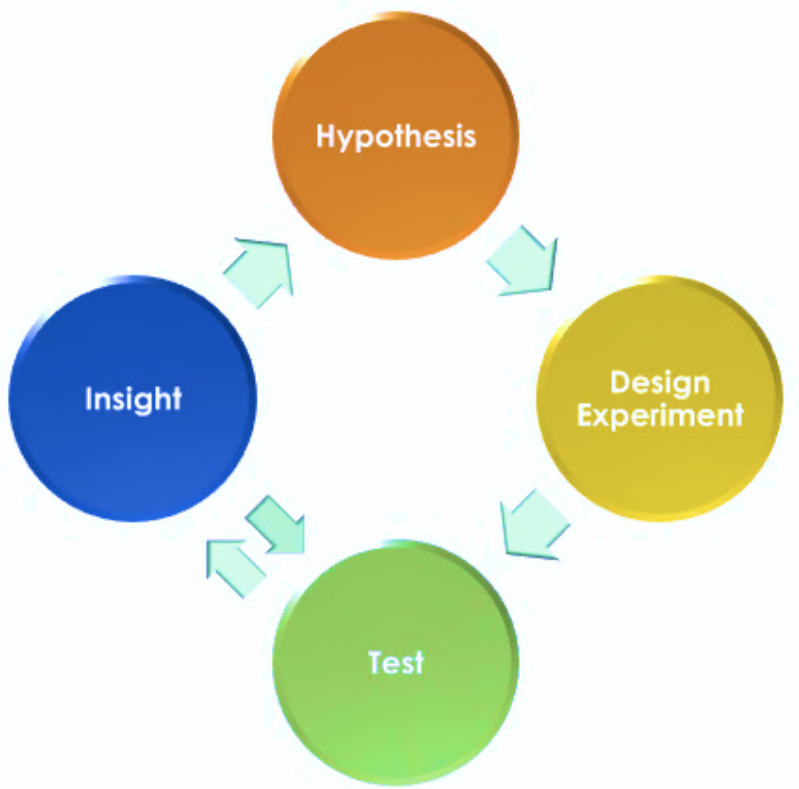
The Penn State Engineering Ambassadors

For you innovators...

Leveraging NSF's Investments in
Research, Commercialization and Entrepreneurship

Education Process

Integrating the Scientific Process and Active Learning



Steve Blank

Source: Steve Blank's "*The Lean LaunchPad*"

Student entrepreneur (EL)

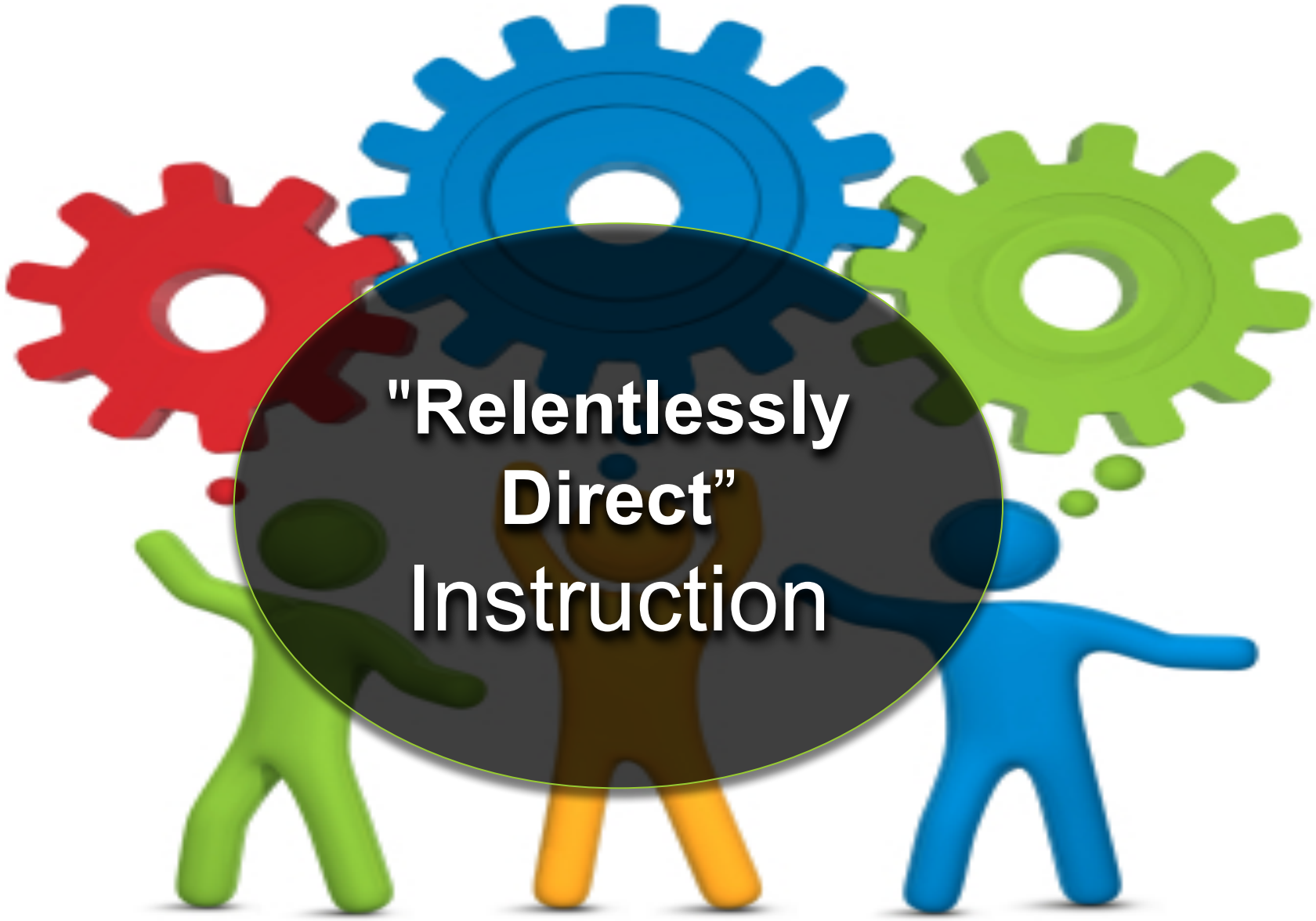
Academic researcher (PI)

Mentor (M)

Student entrepreneur (EL)

Academic researcher (PI)

Mentor (M)



Student entrepreneur (EL)

Academic researcher (PI)

Mentor (M)

Plus:

Contacting Program Officers

- Generally better to email rather than call
- Don’t mass email—multiple POs may work on a program, talking to many creates redundant work

- Online face-to-face or phone meetings are just as good, no need to travel to DC
- **Be prepared to say what you’re asking for:**
  - advice on where to submit an idea
  - feedback on a **one-pager** to a program
  - procedural advice or answers to specific questions

Change the world...

Suggestions

- Don’t repeat past efforts, build upon prior work
  (e.g., *search nsf.gov, www.dia2.org*)
- Ideas w/out actions ≠ change
- Be realistic, identify where all can best contribute
- Form and sustain a community of practice
  (pick 3 best friends)
- **Commit** - *one workshop won’t produce a transformation*

In closing:

Help change the conversation...

An Engineering Degree can provide a strong foundation for any career.

Let's Seize the Moment:

Let's Seize the Moment:

Democratize Engineering

Thank you.