Grand Challenges require innovative solutions

President Darryll J. Pines, University of Maryland

NSF ERC Workshop: October 5,| 2021

Overview

Overview

- Introduction
- 2020: An Inflection Point Year for humanity
- What is the role for science and engineering?
- Grand Challenges of our time (A class)
- Grand Challenges demand Fearless Ideas
- Gen-4 ERC Vision (Convergent Research, Inclusive Teaming, Workforce Development, and Innovation Eco)
- Conclusion

Introduction

Introducing myself

- Part of the University of Maryland for 26 years
  - Assistant professor in 1994
  - Department chair for 3 years
  - Dean of the A. James Clark School of Engineering for 11 years
- Honored to serve as the **34th president**
- NSF Award recipient as PI or co-PI for over 20 years
  - CAREER, ADVANCE IGERT, ICOR, and e4usa
- Served on NSF Engineering Directorate Advisory Committee (ERVA)
- Served on NAE Committee on Center-Based Engineering Research
- Proud member of ASEE for over 15 years
- Started as President on July 1, 2020

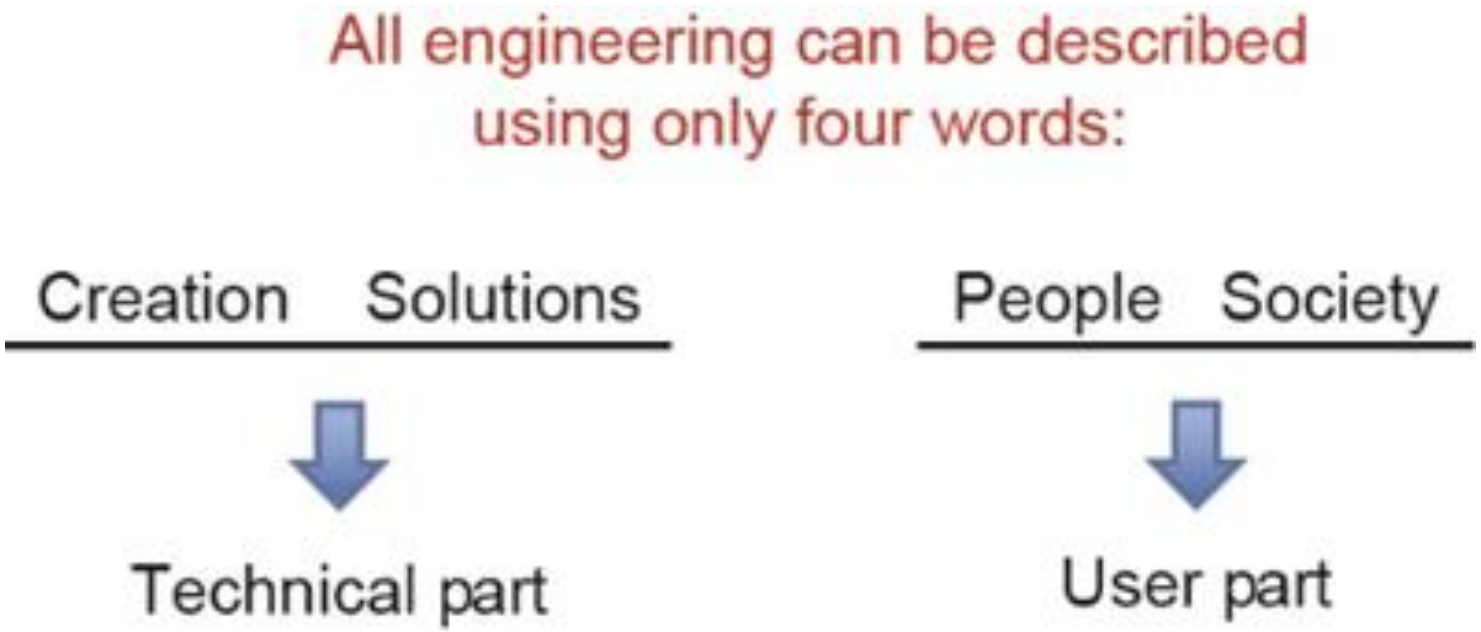
2020: An inflection point year for humanity in the 21st Century- Importance of Engineering

Predict Innovations of 21st Century

- 2007: National Academy of Engineering (NAE) convened 18-person international committee to envision what extraordinary engineering creations might be forthcoming in the 21st century.
- The Committee focused on what engineering needs to achieve in 21st Century based on current challenges at the time.

Technical and User Part of Engineering

- Engineering is a global enterprise and a century long vision must view engineering globally.
- “Engineers create solutions for people and society,” C. Dan Mote



Grand Challenges for Engineering (1998)

NATIONAL ACADEMY OF ENGINEERING

- **Vision:** Continuation of life on the planet, making our world more sustainable, secure, healthy, and joyful.
- **Goals:** Grand Challenge for Engineering
- **Objectives:** Solutions that deliver each goal

Sustainability
Security
Human Health
Enhance Human Life

1. Make Solar Energy more economical
2. Provide Energy from Fusion
3. Develop Carbon Sequestration Methods
4. Manage the nitrogen cycle
5. Provide access to clean water
6. Restore and improve infrastructure
7. Advance Health Informatics

1. Engineer better medicines
2. Reverse engineer the brain
3. Prevent nuclear terror
4. Secure cyberspace
5. Enhance Virtual Reality
6. Advance Personalized Learning
7. Engineer the tools of Scientific Discovery

Achieving this vision statement everywhere would advance human life on the planet everywhere through increased sustainability, security, health and joy or quality of life.

Workforce Development-Talent Group

- In 2008, the NAE launched the Grand Challenge Scholars Program (GCSP) to expose and train future engineers.

- Five Competencies: *Research, Multi-cultural, Multi-disciplinary, Business, and Social Consciousness.*

- 75 University sites in the US hosted approved GCSP programs. Internationally, 17 university programs approved. Over 10,000 diverse students working on the Grand Challenges for Engineering.

Shortfall of NAE Grand Challenges

- Committee did not predict challenges associated with:
  - Infectious Disease
  - Food, water, and energy security
  - Political unrest
  - Racial injustice
  - Wide ranging impact of climate change
  - Concurrent challenges happening at the same time requiring the convergence of multiple disciplines to solve

Swing of the Pendulum in Society

Syndemic | Opportunity

Concurrent Epidemics/ Pandemics:

Covid-19

Social Injustice

Political Uncertainty

Climate Events

Change Happens Everywhere

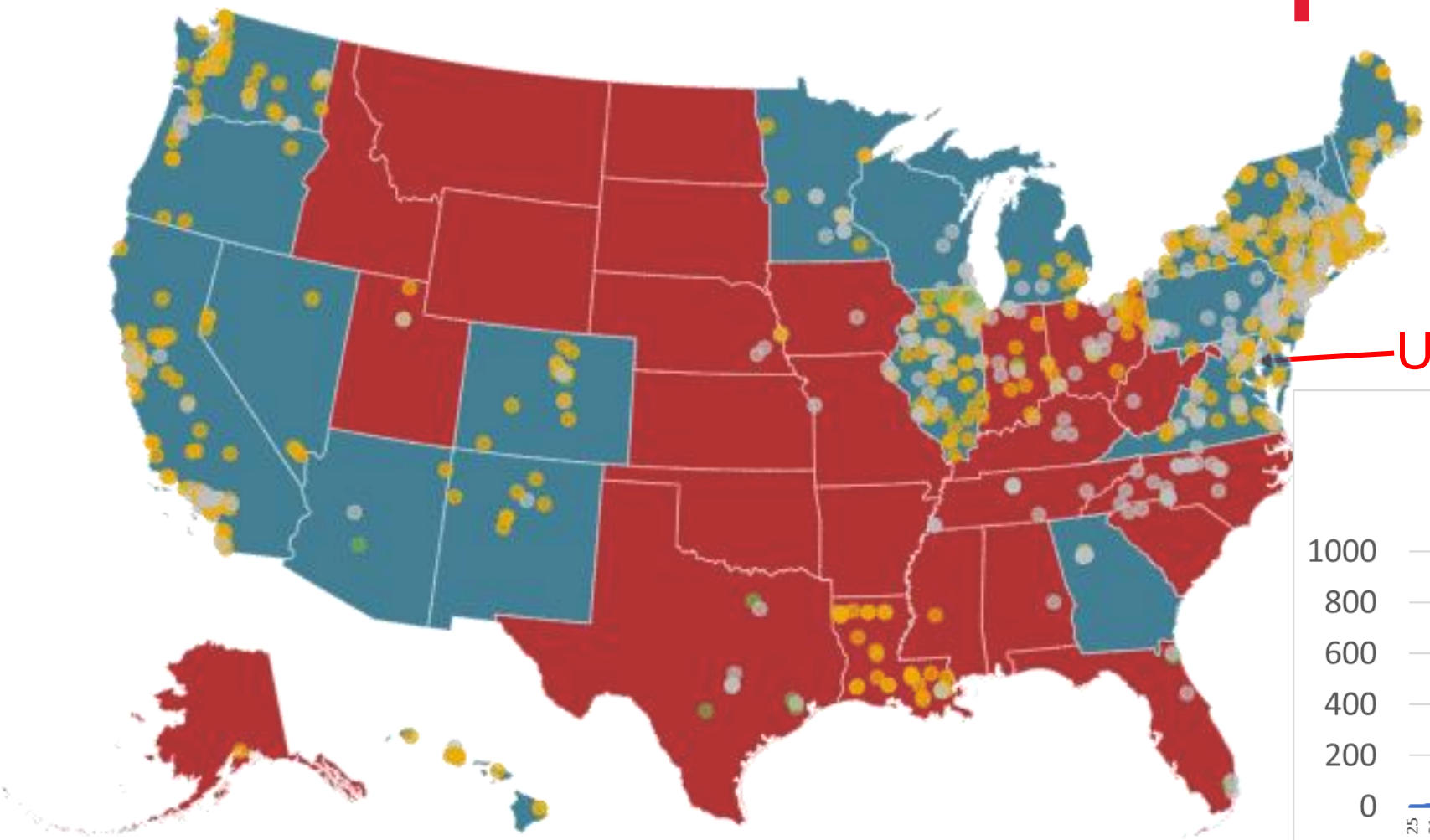
We are globally connected


BLACK LIVES MATTER!
TRAYVON MARTIN
JORDAN DAVIS
ALYANA STANEY-JONES
ERIC GARNER
KATHRYN JOHNSTON
MICHAEL BROWN
OSCAR GRANT
SANDRA BLAND
ALTON STERLING
AKAI GURLEY
TERAKE REED
YVETTE SMITH
TAMIR RICE
REKIA BOYD
JAMEL FLOYD
ATATIANA JEFFERSON
STEPHON CLARK
BOTHAM JEAN
GEORGE FLOYD
DAVID MCATEE
RAYSHARD BROOKS
MANUEL ELLIS
BREONNA TAYLOR
AHMAUD ARBERY
IF YOU ARE NOT ANTIRACIST YOU ARE COMPLICIT
2 Divest from PGPD
Sign your
Support
here + share

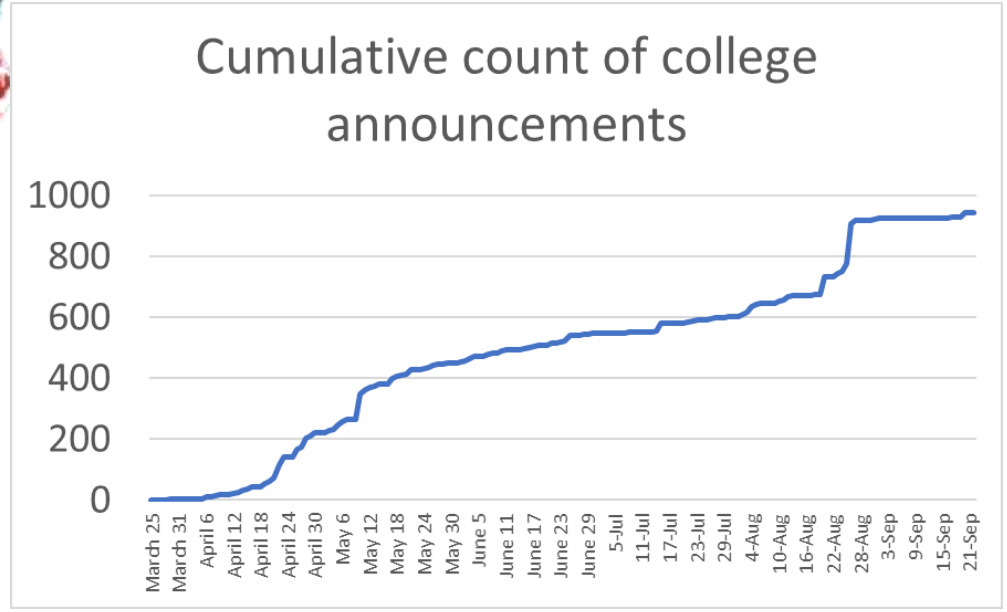
Covid-19 revealed several problems

- Global Access to healthcare
- Food insecurity (Food Deserts)
- Poverty
- Health disparities between population groups
- Gaps in access to technology including broadband, devices, software, and education and employment opportunities
- Lack of preparedness for epidemics, pandemics and syndemics
- Public health decisions are influenced by politics

Vaccination Campus Map

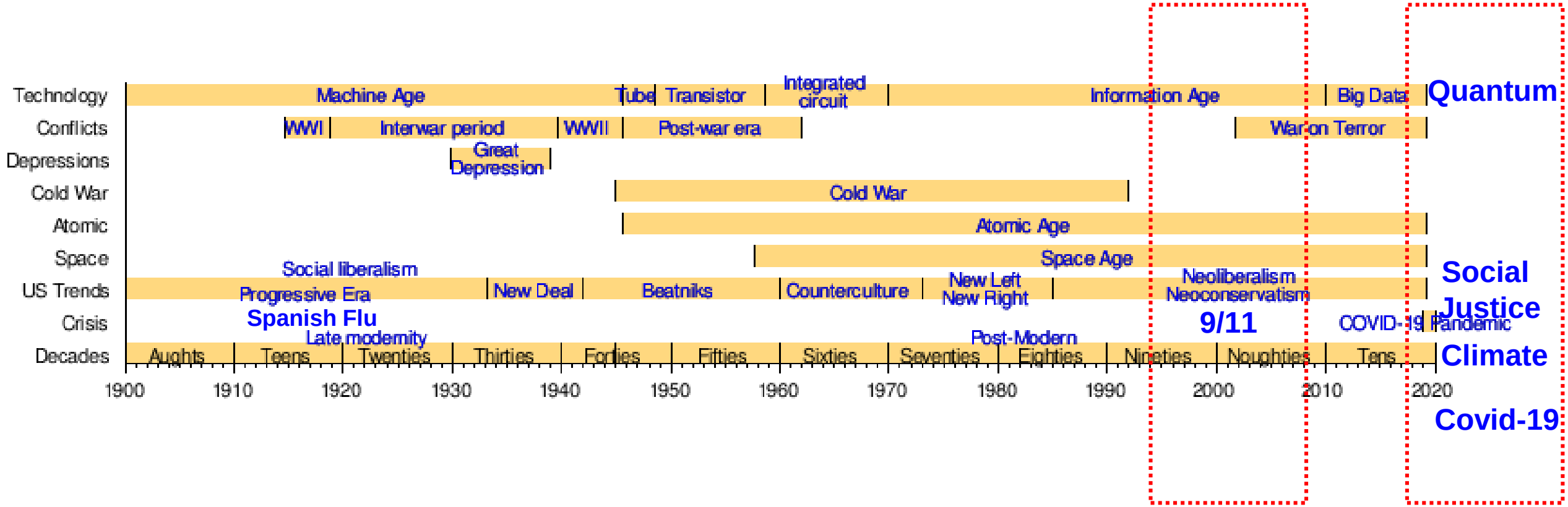


Science and Public Health has been politicized



Orange: Public Universities
Gray: Private Universities

Watershed Moments in last 100 years on the Planet

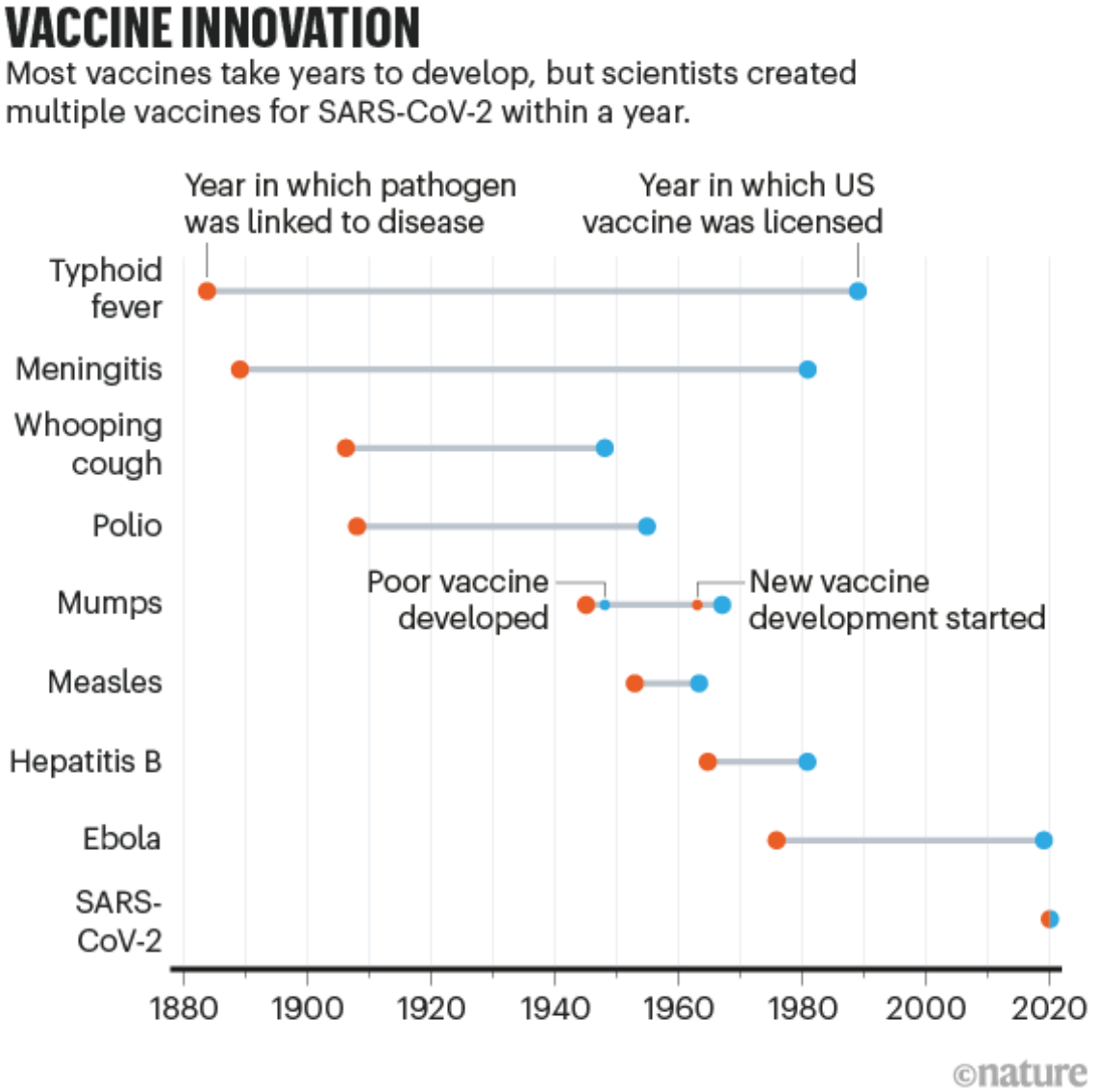


What is the role for science and engineering in society?

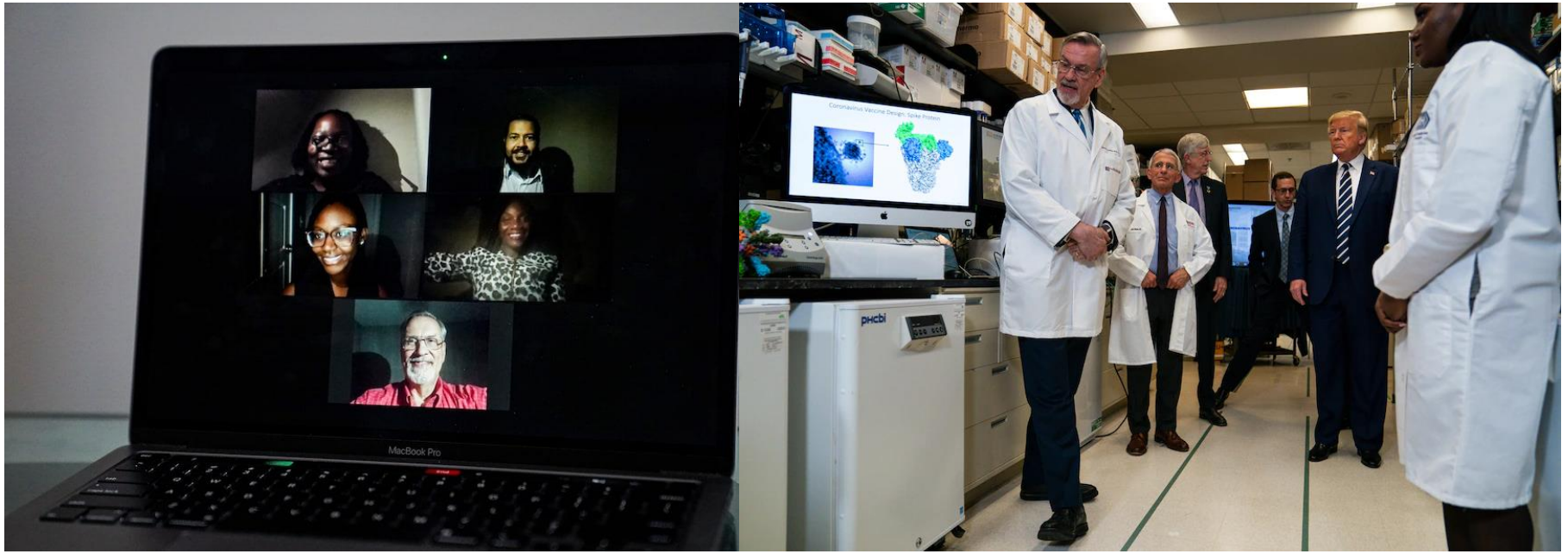
What is the role of Science and Engineering?

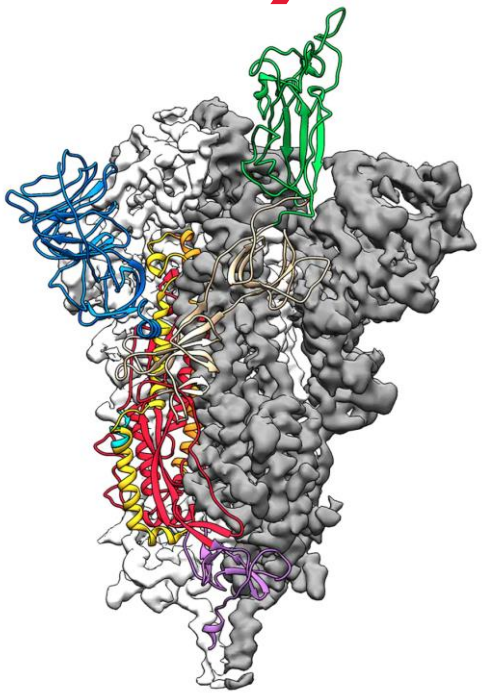
- Develop evidence based solutions
- Example: Investment in messenger RNA based Therapeutics.
- Acceleration of Vaccine Development Process.

Covid-19 Vaccine:
12 to 18 months



NIH Team that uncovered the Coronavirus Spike Protein (Inclusive Excellence)





3D Structure of Coronavirus Spike Protein

It took 66 days from the genome being published to the Moderna vaccine being injected into people.

https://www.washingtonpost.com/health/2021/10/01/barney-graham-covid-vaccines/

We inspire hope by Engineering Solutions

mRNA Vaccines (Data from early January 2021)

Pfizer Vaccine

- Prefusion spike transcript
- 2 doses 21 days apart
- VE=95% efficacy
- 162 cases of symptomatic disease in placebo; 8 in vaccine
- 10 cases of severe disease; 9 in placebo, 1 in vaccine
- VE 94% in those > 65

Moderna Vaccine

- Prefusion spike transcript
- 2 doses 28 days apart
- VE=94.5% efficacy
- 90 cases of symptomatic disease in placebo; 5 in vaccine
- 11 cases of severe disease; all 11 in placebo group
- No difference in VE by age and ethnicity

Grand Challenges

GRAND CHALLENGES
OF OUR TIME

Course taught by President Pines

The ultimate measure of a man is not where he stands in moments of comfort and convenience but where he stands in times of challenge and controversy.

Martin Luther King, Jr.

Grand Challenges of Our Time Course

- COVID-19 and vaccines. Black Lives Matter and social unrest. Climate change. Civic engagement.
- New students were introduced to national and campus experts working on today's most pressing problems
- 8-week course comprised of weekly lectures for first year students
- Small group meetings, facilitated by faculty and staff, to discuss one of the topics featured in the weekly lectures.
- Grand Challenges of Our Time Presidential Distinguished Forum open to entire campus community
- Teaching the course again this fall

Topics and Invited Speakers: Fall 2021

2021 MacCarthur Fellow

- Reginald Dwayne Betts ’09
  - Incarceration reform advocate
- Philonise Floyd
  - Criminal Injustice
- Mona Hanna-Attisha
  - Environmental Injustice: Public Health expert : “What the eyes don’t see”

Grand challenges of our time - University of Maryland (umd.edu)

We all will become Super Heroes: Coronavirus Avenger

When historians pick up their pens to write the story of the 21st century, let them say that it was your generation who laid down the heavy burdens of hate at last and that peace finally triumphed over violence, aggression and war..

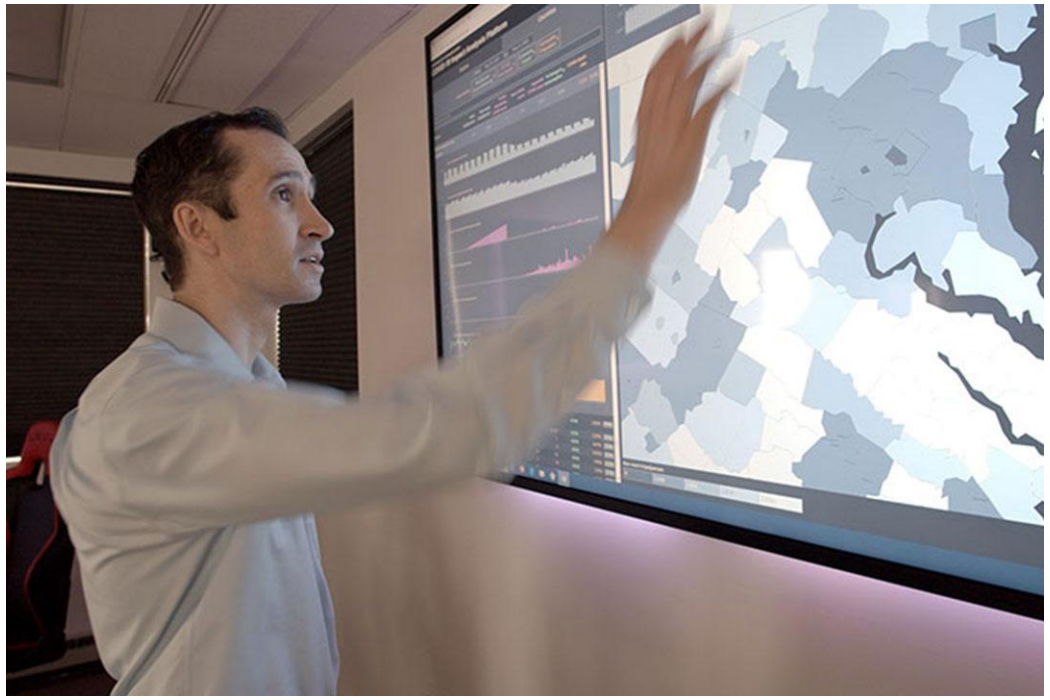
Congressman John Lewis
NY Times, 2020

Grand Challenges Demand Fearless Ideas from Engineers

Responding to COVID-19

COVID-19 Impact Analysis Platform: Informing difficult decisions (Dr. Lei Zhang (CEE, MTI))

- Tracking national travel, epidemiological, and socio-economic trends to measure the pandemic's impact on the society
- Developed by Maryland Transportation Institute, ran by 11 graduate students
- Providing data to CDC, U.S. Departments of Transportation, Treasury, Veterans Affairs, FRS, and other federal and state organizations



Responding to COVID-19

Mobile COVID-19 Testing Booths: Protecting first responders and the community

- Low-cost, rapidly deployable mobile testing booth
- Clean environment, no PPE needed

Fighting Social Injustice

Dr. Alyssa Clyne (BioE) and her fearless students work to improve socioeconomic, sex, and ethnic diversity in cardiovascular disease research and create therapies for the people who need them most

Fighting Social and Environmental Injustice

Six UMD undergraduates study fire safety inequities around the world to help vulnerable communities back at home

Distinguishing Features of a Gen-4 ERC

A New Vision for Center Based Engineering Research

RECOMMENDATION: The National Science Foundation (NSF) should re-invigorate the Engineering Research Center concept by addressing grand-challenge-like problems whose solutions offer the greatest benefits for society and by adhering to the use of best team-research and value-creation practices, fewer administrative burdens, and greater investment and prestige to attract the superb, diverse talent required.

To emphasize the ambition and the bold new direction of these center-scale investments led by engineering, they should be given a new name, possibly **Convergent Engineering Research Centers (CERCs).**

The CERC Vision has Two Components

1.Shift from the current focus on developing a promising new technology area to addressing a big, high-impact societal or technological need through convergent engineering research. Examples include: NAE Grand Challenges; ideas from the Bill and Melinda and Gates Foundation; Millenium Project; other Grand Challenge Proposals.

Tackling grand-challenge-like problems will:

- Create excitement in the engineering community and attract the best talent
- Attract more women and under-represented minorities to engineering

It will also require:

- Larger budgets, whether through fewer centers or cost sharing
- Streamlined reporting and enhanced collaboration with host institutions
- Systematic strategies for managing the diverse and distributed teams

The CERC Vision has Two Components-cont

2. Systematically adapt team-research and value-creation best practices, such as those currently used by the Defense Advanced Research Projects Agency (DARPA) and top U.S. companies, to a multidisciplinary university center environment.

Examples include: Agile, Scrum, Lean, Six Sigma, the Five Disciplines of Innovation, and DARPA calls theirs “Special Forces” Innovation. Experience in implementing these practices has shown that dramatic improvements in performance are possible. Also leads to diverse teams of researchers working together.

Potential CERC Models

Grand-challenge-based model. The example discussed is based on the NAE Grand Challenge of “advancing personalized learning.”

Prize-based model. In this model, NSF would oversee a new generation of technology innovators hoping to be the first team to achieve competition milestones and claim a cash prize. The prize is awarded to the best approach to one technical thrust within the broader center mission. An example discussed in the report is Elon Musk’s Hyperloop Pod Design Competition.

Federal-state-local partnership model. This model would tap the genius of a broad cross-section of the research community to stimulate local or regional innovation on topics such as developing practical approaches to dealing with the joint issues of sea level rise and extreme weather events for coastal cities.

Comparison of Engineering Research Center (ERCs) and Convergent Engineering Research Center (CERCs

ERCs	CERCs
Multidisciplinary research primarily focused on technological innovation	Transdisciplinary research focused on high-impact societal challenges and exploiting technological convergence
Emphasis on creating economic value by enhancing U.S. innovation ecosystems	Emphasis on maximizing societal value, which will lead to greater economic value
Strategic planning based on proceeding from fundamental research through enabling technology research to systems research (test beds)	Strategic planning based on systematic application of best practices in value creation
Researchers and students collaborate through regular meetings and discussions	Deep research collaboration using both in-person meetings and virtual technology platform, best in team research practices
Approximately 20 centers operating at any one time with NSF funding supplemented by industry partner memberships as well as state and local funds	Larger center budgets through reducing the number of centers or supplementary funding

Comparison of Engineering Research Center (ERCs) and Convergent Engineering Research Center (CERCs

ERCs	CERCs
One basic structural model	Experimentation with various structural models
Students benefit from interaction with center faculty from multiple disciplines and industry mentors	Students gain experience with best practices in convergent engineering research
Pre-proposal process helps to ensure that the final proposal meets all requirements	Rigorous, staged pre-proposal process to refine the problem to be addressed and choose the right teams
Center directors must answer to numerous boards and site visit recommendations	Center directors given more authority and autonomy from NSF and site-visit groups
Extensive reporting requirements for annual reports and post-graduation plans	Lean reporting requirements and use of software tools to capture outcomes
Performance metrics largely based on outputs	**Performance metrics based on outcomes and impacts**
Sunset after 10 years but with the expectation of the center continuing with other support	Opportunity to re-compete after 10 years if transformational results being achieved

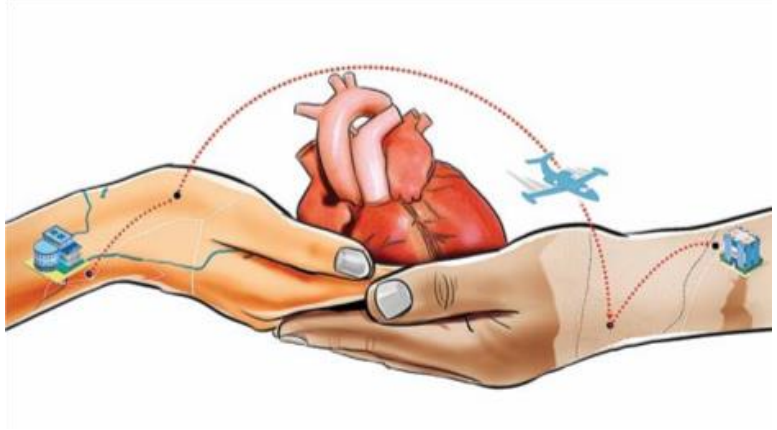
Gen-4 ERC
(NSF Working Group Recommendations)

Convergent Research and **Innovation** through **Inclusive Partnerships** and **Workforce Development**

- Emphasizes **societal impact**, **convergence**, **stakeholder community**, and **team formation**
- Demonstrable **integration** of **foundational components**
- Increase award size to **max $6M/year**
- **Planning grant** opportunity to enhance convergent team formation

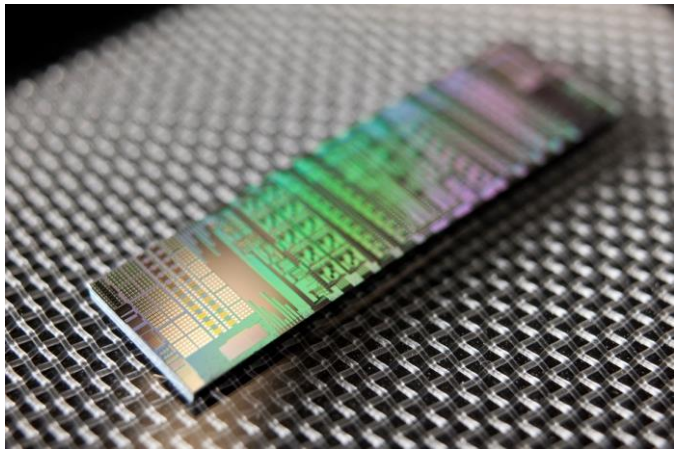
FY20 New Gen-4 NSF ERCs

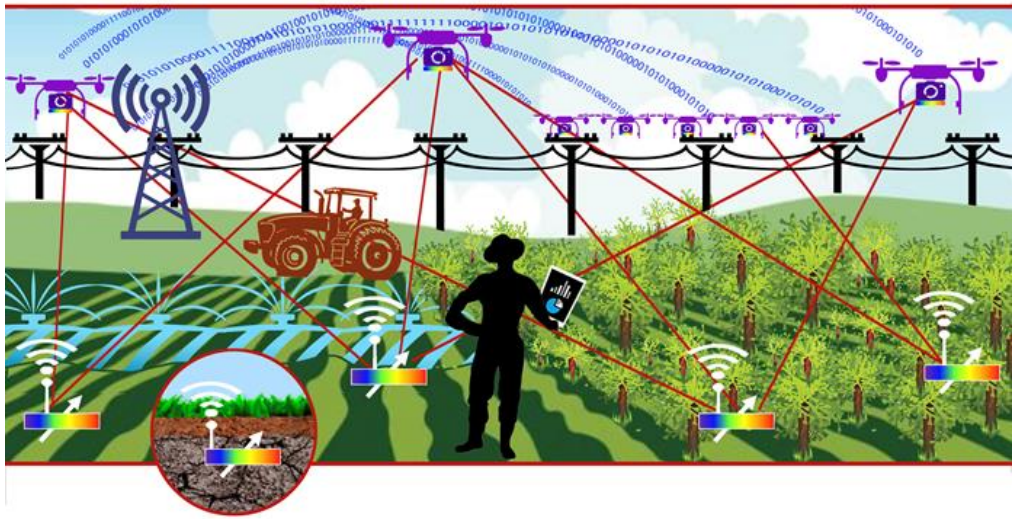
- **Advancing Sustainability through Powered Infrastructure for Roadway Electrification (ASPIRE)** - Create sustainable, equitable and widespread electrification of vehicles by creating low-cost, ubiquitous, and worry-free charging infrastructure.
- **Advanced Technologies for Preservation of Biological Systems (ATP-Bio)** - Stop biological time by cryogenically cool, hold and re-warm living materials (cells, tissues, organs and whole organisms), extend ability to bank and transport.



FY20 New Gen-4 NSF ERCs

- **Center for Quantum Networks (CQN)** - Create foundations for the future quantum internet by developing key quantum technologies and new functional building blocks connecting quantum processors over local and global scales.
- **Internet of Things for Precision Agriculture (IoT4Ag)** - Ensure food, energy and water security with new systems to increase crop production while minimizing energy and water use and environmental impacts of agricultural practices.





Engineering for US All (E4USA) Program

- E4USA is a national pilot program for a high school engineering course.
- E4USA provides a standardized educational curriculum for pre-college students to learn and demonstrate engineering principles, skills and practices.
- The curriculum incorporates an authentic, design-based experience and affords students the opportunity to earn college credit at participating colleges and universities.

"Our goal is to democratize engineering for all,"
Dr. Don Millard (EEC), PO, NSF, 2018
"Every high school student should learn the principles of engineering",
Darryll Pines (PI)

Website: https://e4usa.umd.edu/

engineering 4 us all

National Science Foundation
WHERE DISCOVERIES BEGIN

Conclusion

Conclusions

- Engineers create solutions for people and society.
- Your ERC topics must focus on the grand challenges facing people and society.
- Your ERC teams must be interdisciplinary and trend towards convergent research and innovative solutions.
- Your ERC teams must address workforce development to train the future technical leaders who can be inspired to work on these grand challenges. Leverage GCRP and NSF sponsored programs like e4usa.org.
- Your ERC teams must demonstrate inclusive partnerships that broaden participation and impact.

Driving The Conversation at The Decision-Making Table

Engineers should lead the way shaping the future of society and the world to address the Grand Challenges or our time.

Thank you!

Questions?