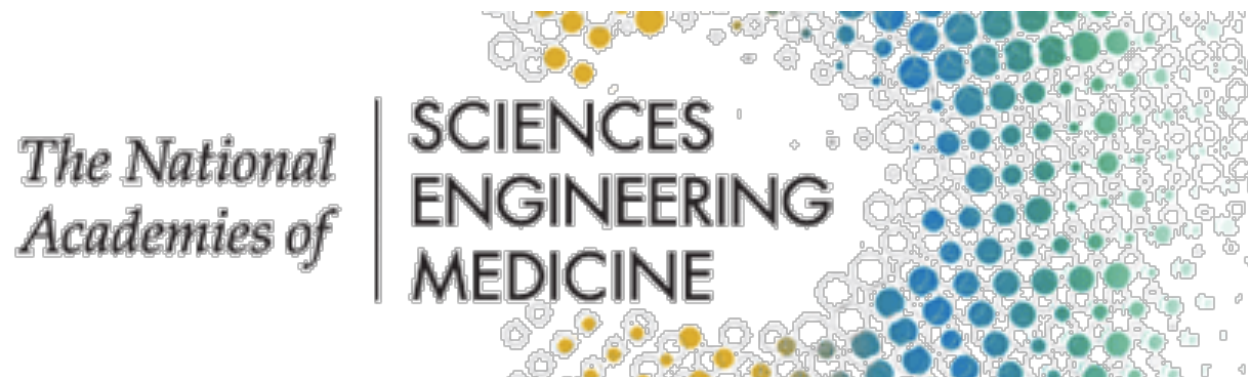
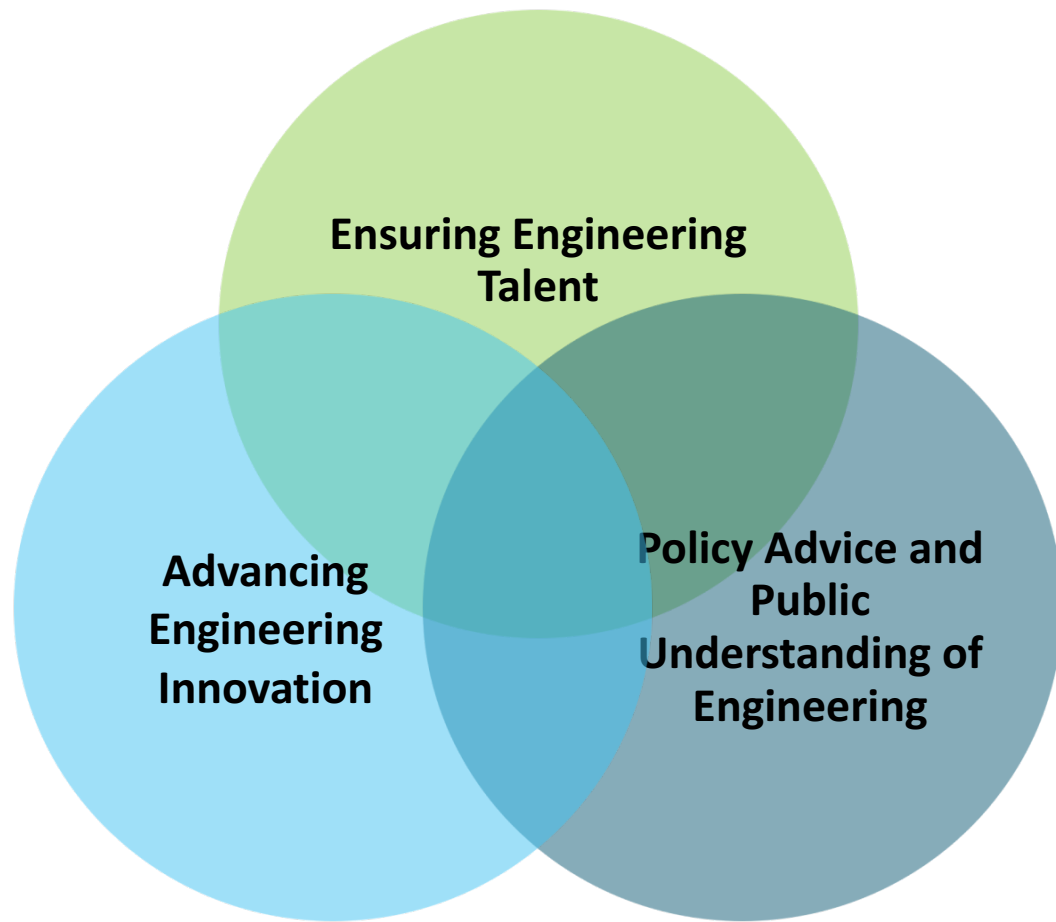


# **Engineering: The Enabling Discipline of the 21<sup>st</sup> Century**

**Grand Challenges Scholars Program Workshop  
Belo Horizonte, Brazil  
August 5, 2019**

**B.L. Ramakrishna  
National Academies of Science, Engineering and Medicine**



Central Position of  
National Academy of  
Engineering

# Grand Challenges for Engineering: A Growing Global Movement



**Engineering in an  
Unpredictable World:  
London, UK**

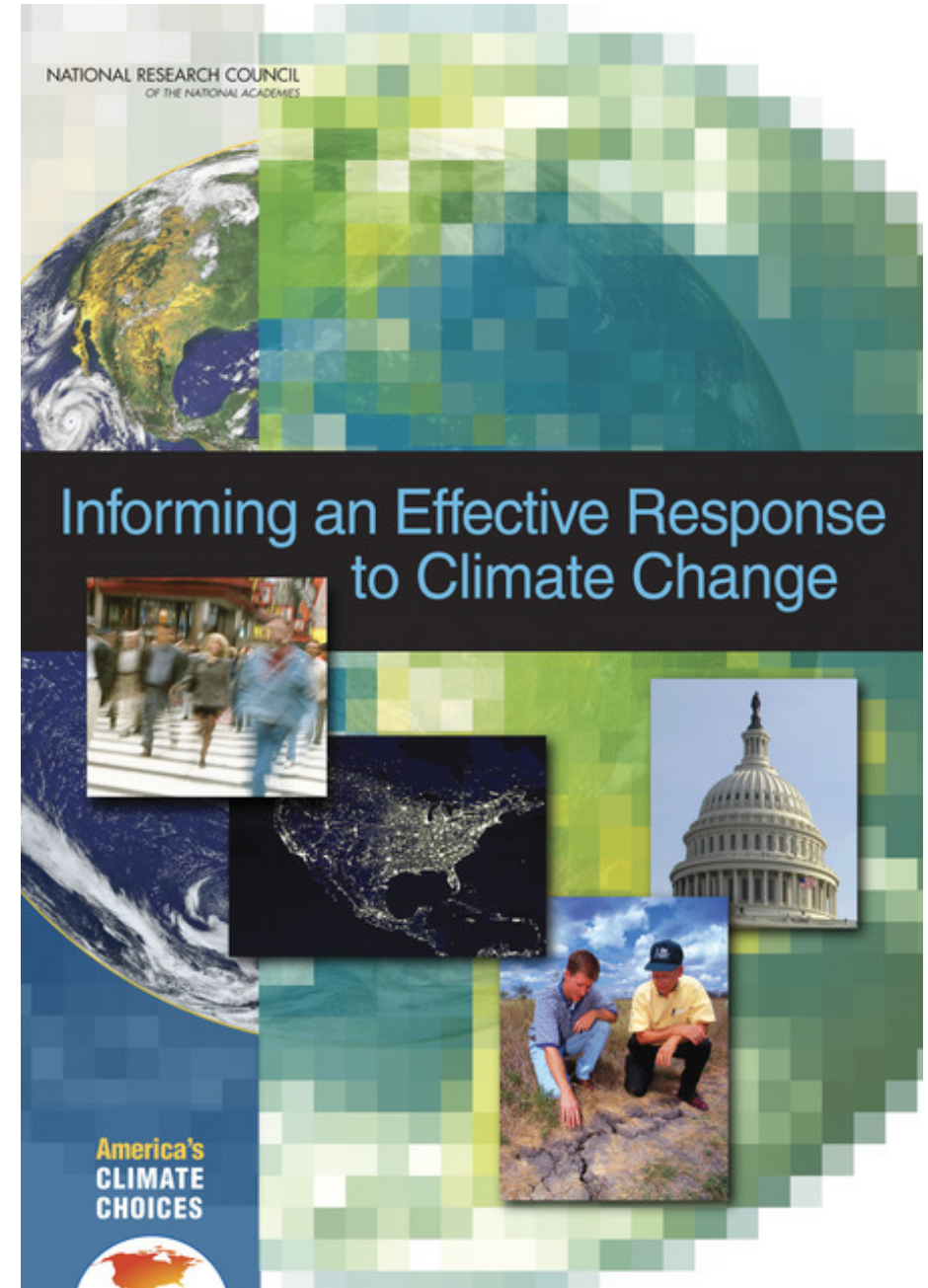


**16-18 September 2019**



- **Climate change is happening today**
- **The evidence is clear and compelling**
- **Humans are Changing Earth's Climate**
- **Climate change is affecting people's lives**

[HTTP://WWW.NAP.EDU](http://www.nap.edu)





# Takeaways

Learn from the Past and be Inspired to Invent the Future

Engineering : Exponential and Convergent

We are all in this Together





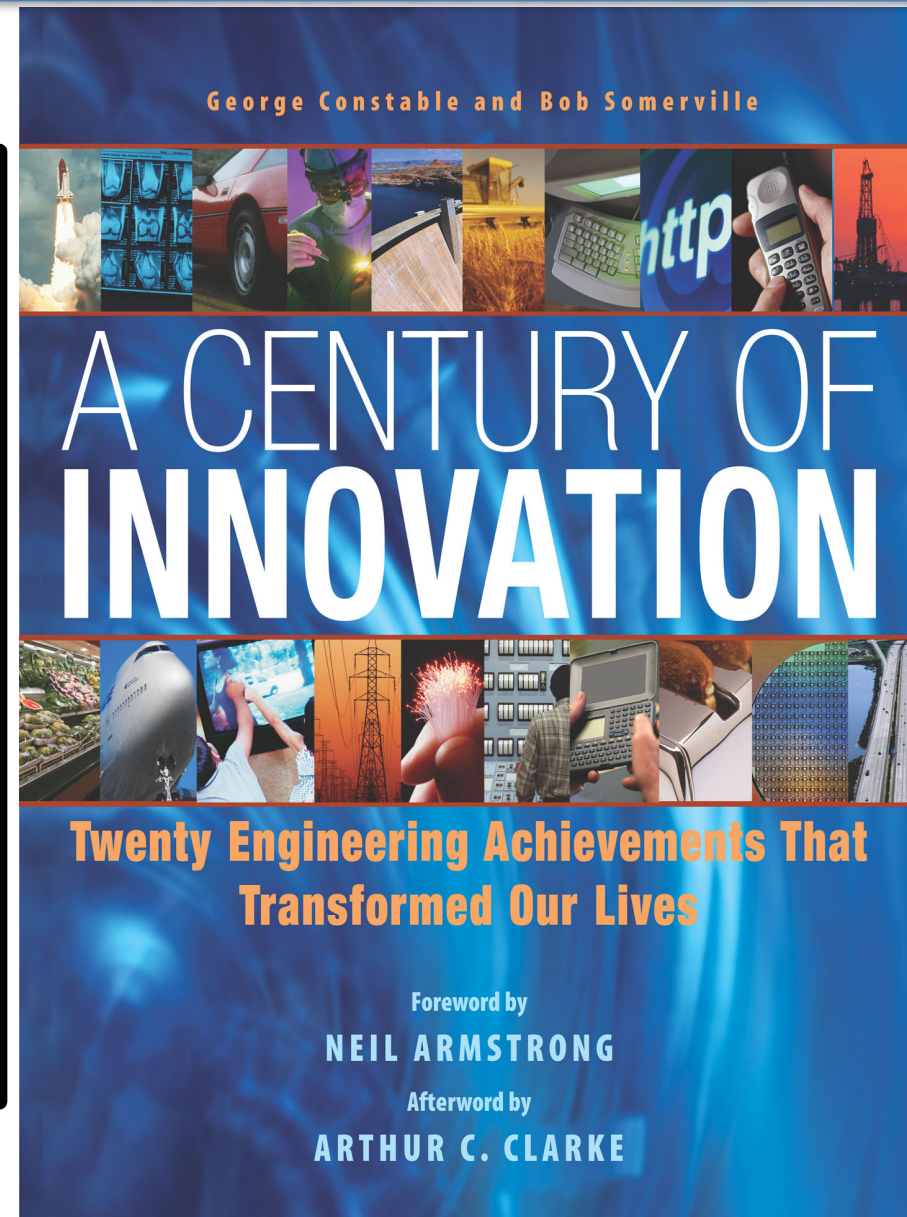
Past is an old man gazing down the corridors of time. He holds a closed book representing history. The inscription, a paraphrase of Confucius, reads: **"Study the Past"** (Study the past if you would divine the future).

In contrast, Future is youthful woman gazing in contemplation of things to come. She holds an open book symbolizing what has yet to be written. **"What is Past is Prologue,"** from Shakespeare's *Tempest*.



# Twenty Greatest Engineering Achievements of the 20<sup>th</sup> Century

The dawn of the new millennium presents an opportunity not only to look ahead to the future, but also to reflect on the ingenuity and inventions of the past.



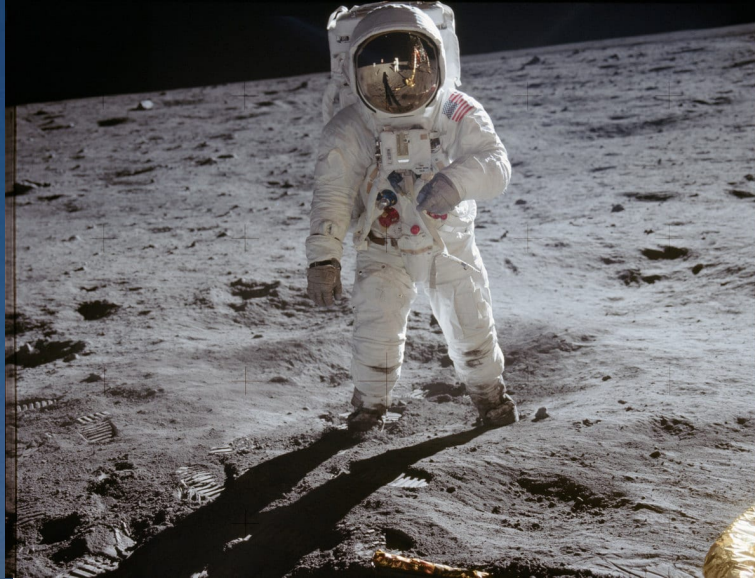
1. Electrification
4. Water supply & distribution
5. Electronics
8. Computers
- 12. Space Flight**
13. Internet
16. Health Technologies
20. High Performance Materials

<http://www.greatachievements.org/>



July 20, 2019

# What will be our Moonshots?

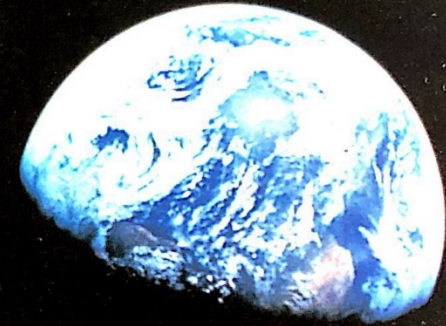


“One small step for man,  
one giant leap for mankind.”

**Neil Armstrong on July 20 1969**  
August 5, 1930 – August 25, 2012

 NATIONAL ACADEMY OF ENGINEERING

## HUMAN SPACE FLIGHT



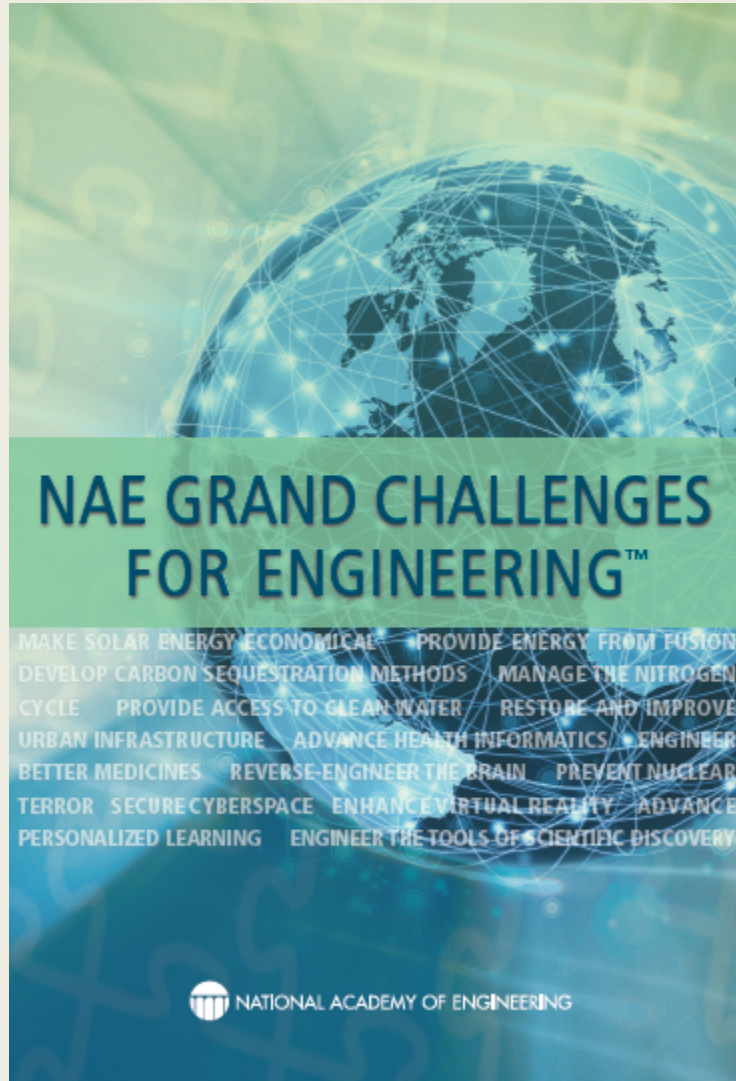
APOLLO 50 YEARS ON

2019 ANNUAL MEETING

October 6-7, 2019  
Washington, DC

*The National Academies of*  
SCIENCES • ENGINEERING • MEDICINE

# NAE Report 2008



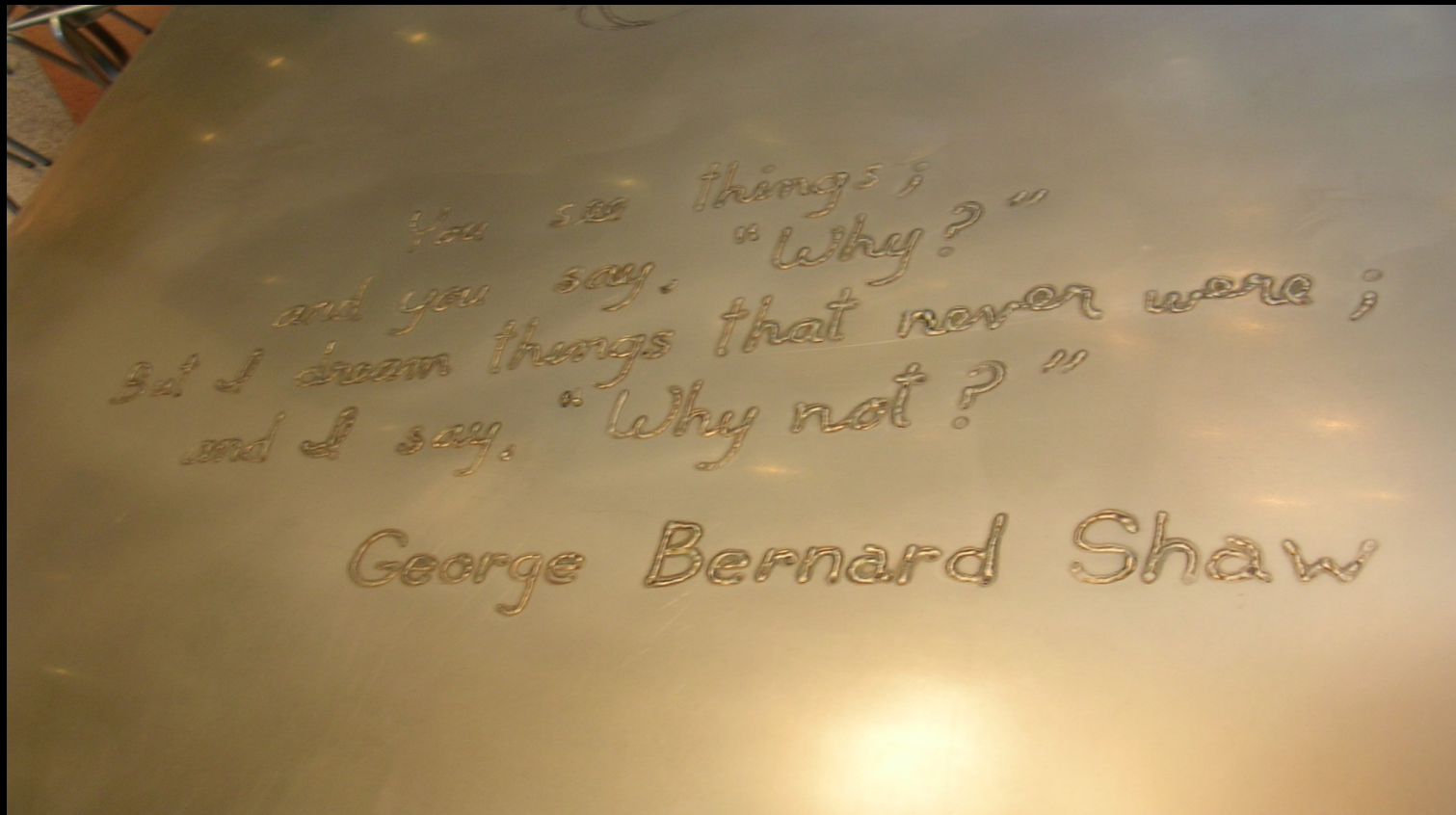
**INSPIRE**

**CHALLENGE**

**EDUCATE**

<http://www.engineeringchallenges.org/File.aspx?id=11574&v=34765dff>





You see things as they are and say “why?”

But I dream things that never were and I say “why not?”

- George Bernard Shaw *“Back to Methuselah”*



# An Inspiring Definition of Engineering

Engineers **Create Solutions** for the **Welfare of Humanity** and the **Needs of Society**

Value Propositions:  
**Creation, Solutions, Humanity and Society**

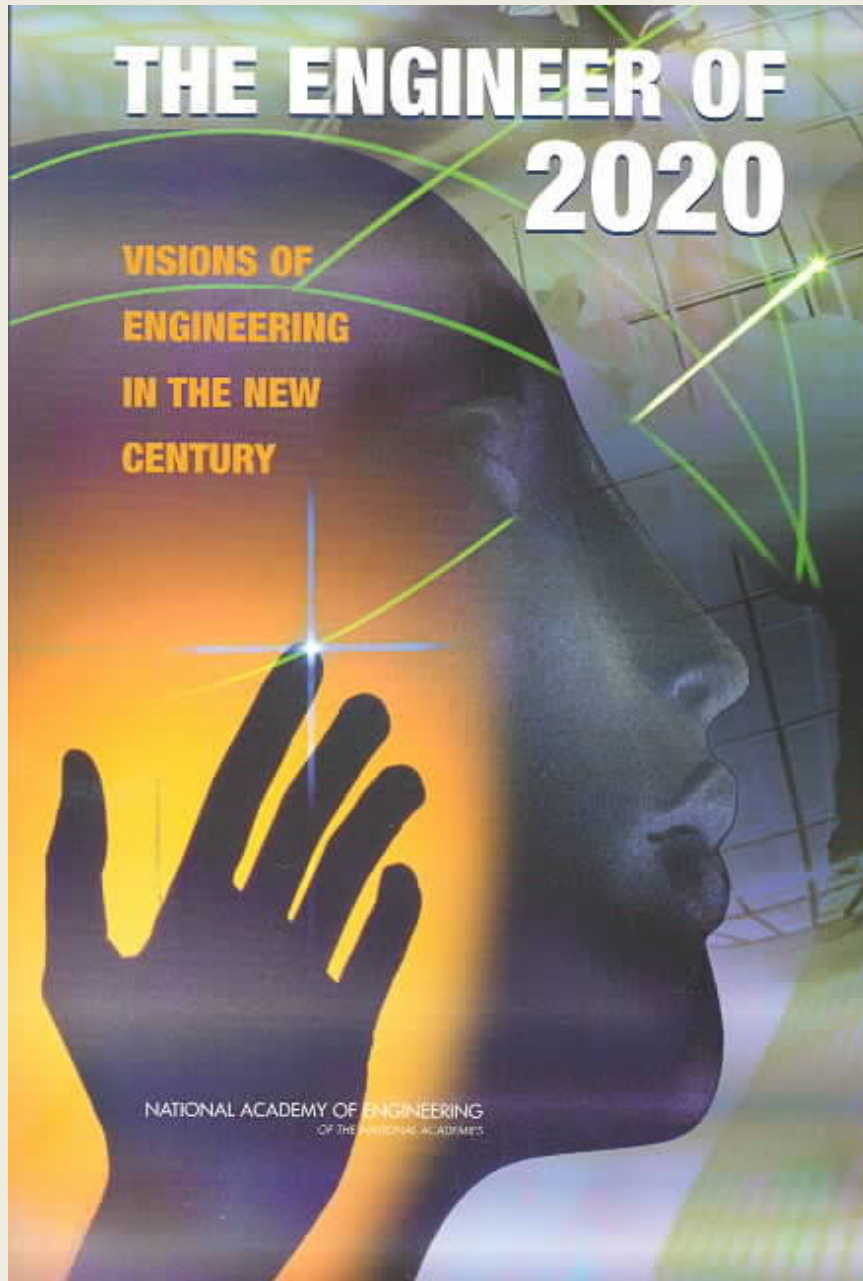
# Vision for Engineering in the 21<sup>st</sup> Century

**Vision:** Continuation of life on the planet, making our world more sustainable, safe, healthy, and joyful

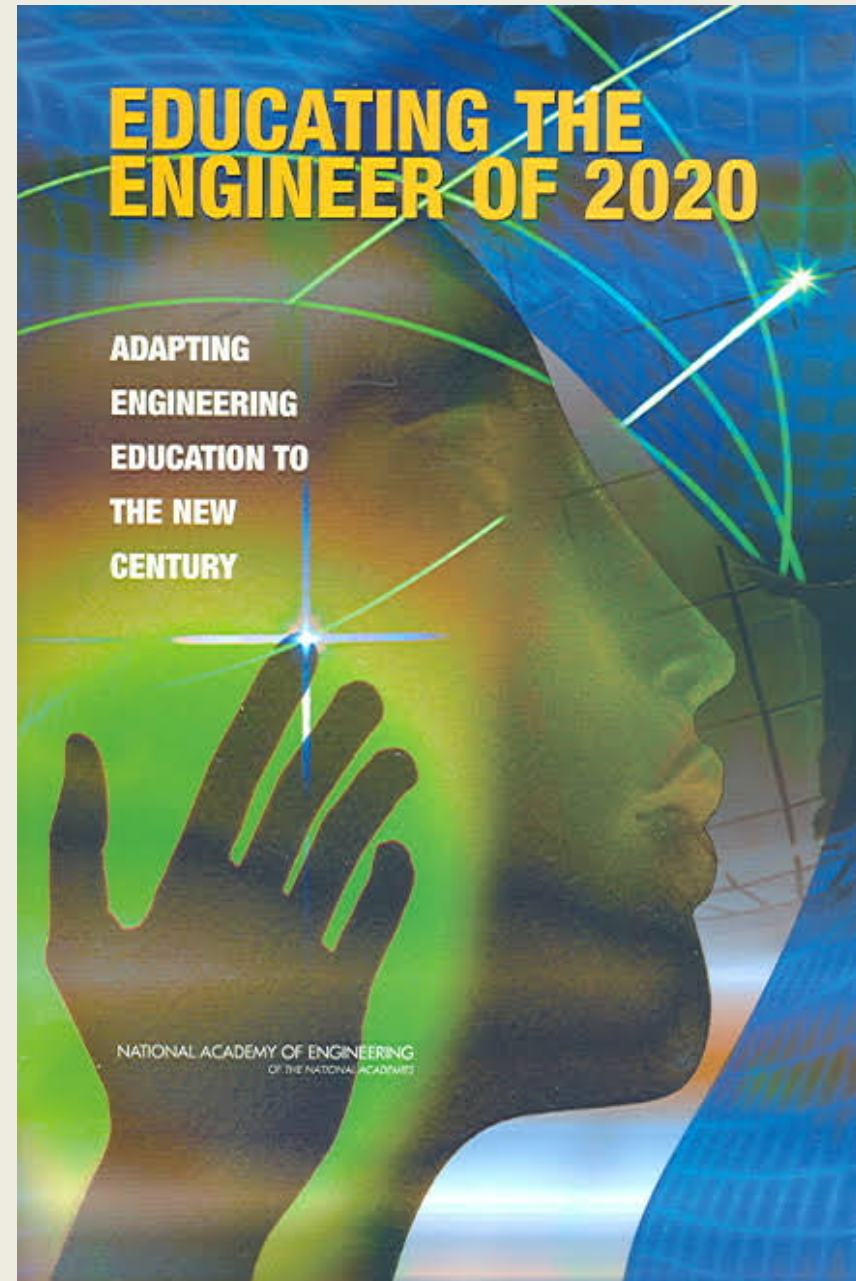
**Goals:** Grand Challenges for Engineering

**Objectives:** 1. R & D Effort - Advance the Frontiers  
2. Talent Building – Inspire the Next Generation

## NAE Report 2004



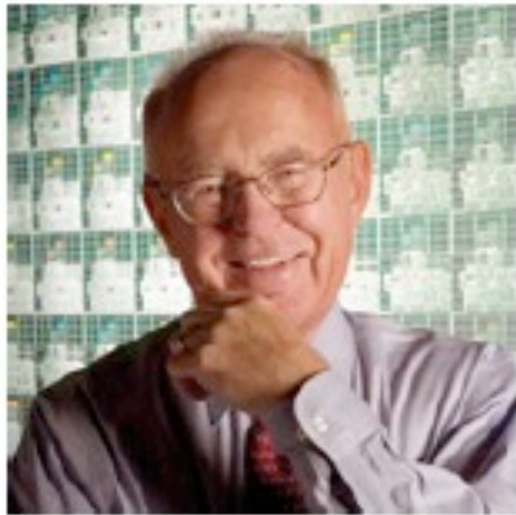
## NAE Report 2005





In the face of grand challenges for engineering, several efforts have been undertaken to identify the vision for what we should expect from our undergraduate engineering students.

-----“Engineer of 2020” NAE Report 2004



**The Engineer of the 21st Century** *will aspire to have*

*the **ingenuity** of Lillian Gilbreth,  
the **problem-solving capabilities** of Gordon Moore,  
the **scientific insight** of Albert Einstein,  
the **creativity** of Pablo Picasso,  
the **determination** of the Wright Brothers,  
the **leadership abilities** of Bill Gates,  
the **conscience** of Eleanor Roosevelt,  
the **vision** of Martin Luther King, and  
the **curiosity and wonder** of our grandchildren.”*

**“Engineer of 2020” NAE Report 2004**

# Grand Challenges Scholars Program

- Research/Creativity : *Depth*
- Multidisciplinarity : *Breadth*
- Business/Entrepreneurship : *Viability*
- Global/Multicultural : *Planetary Vision*
- Social consciousness : *Desirability*

***Engineering+***





# NAE's Engineering Grand Challenges



Make Solar Energy  
Economical



Provide Energy  
From Fusion



Develop Carbon  
Sequestration  
Methods



Manage the  
Nitrogen Cycle



Provide Access  
to Clean Water



Restore and  
Improve Urban  
Infrastructure



Advance Healthcare  
Informatics



Engineer Better  
Medicines



Reverse  
Engineer the  
Brain



Prevent Nuclear  
Terror



Secure  
Cyberspace



Enhance  
Virtual  
Reality



Advance Personalized  
Learning



Engineer the  
Tools of Scientific  
Discovery





## Engineering Research Center (ERCs)

- Multidisciplinary research
- Primary focus on technological innovation
- Emphasis on creating economic value

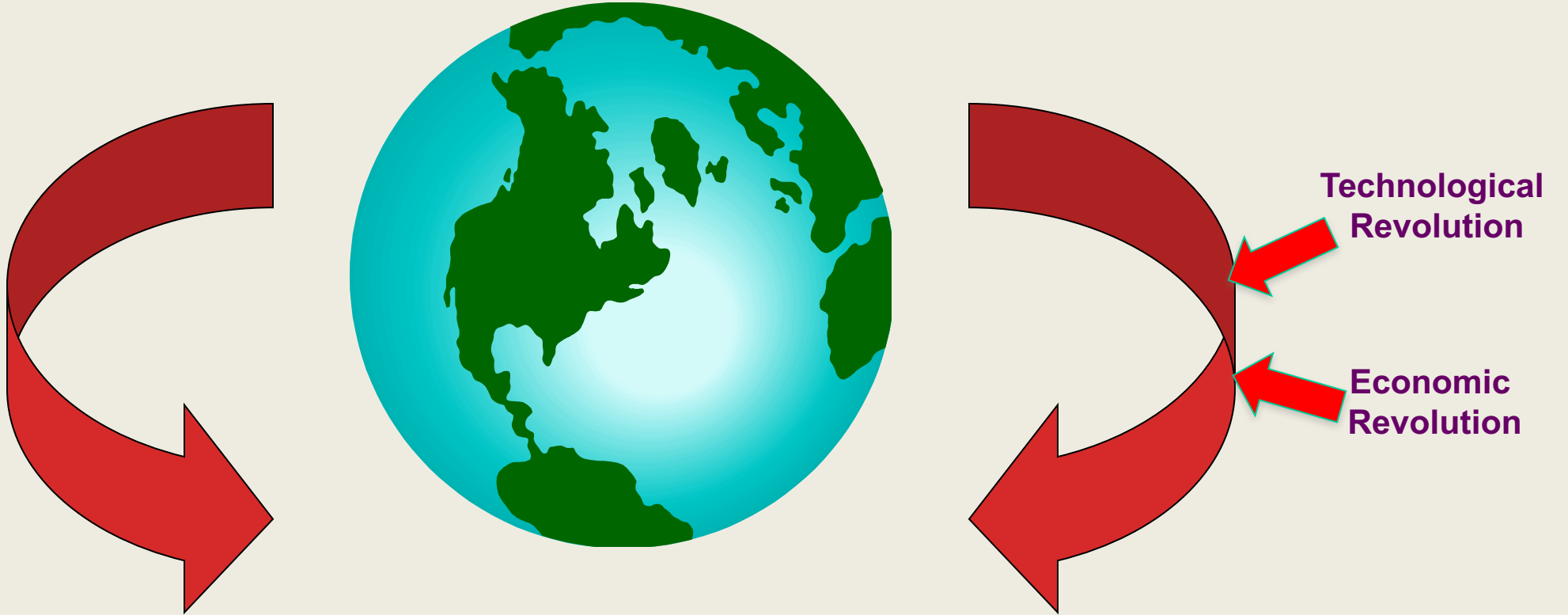
## Convergent Engineering Research Center (CERCs)

- Transdisciplinary research
- Focus on high-impact societal challenges
- Exploiting technological convergence and
- Bringing in the social sciences as appropriate
- Emphasis on maximizing societal value

# A Beleaguered Planet

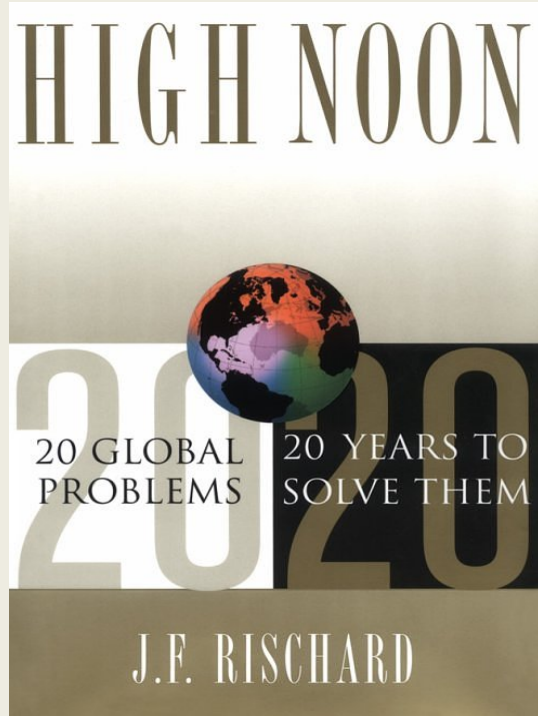
**Demographic Explosion**

**Global Economy**



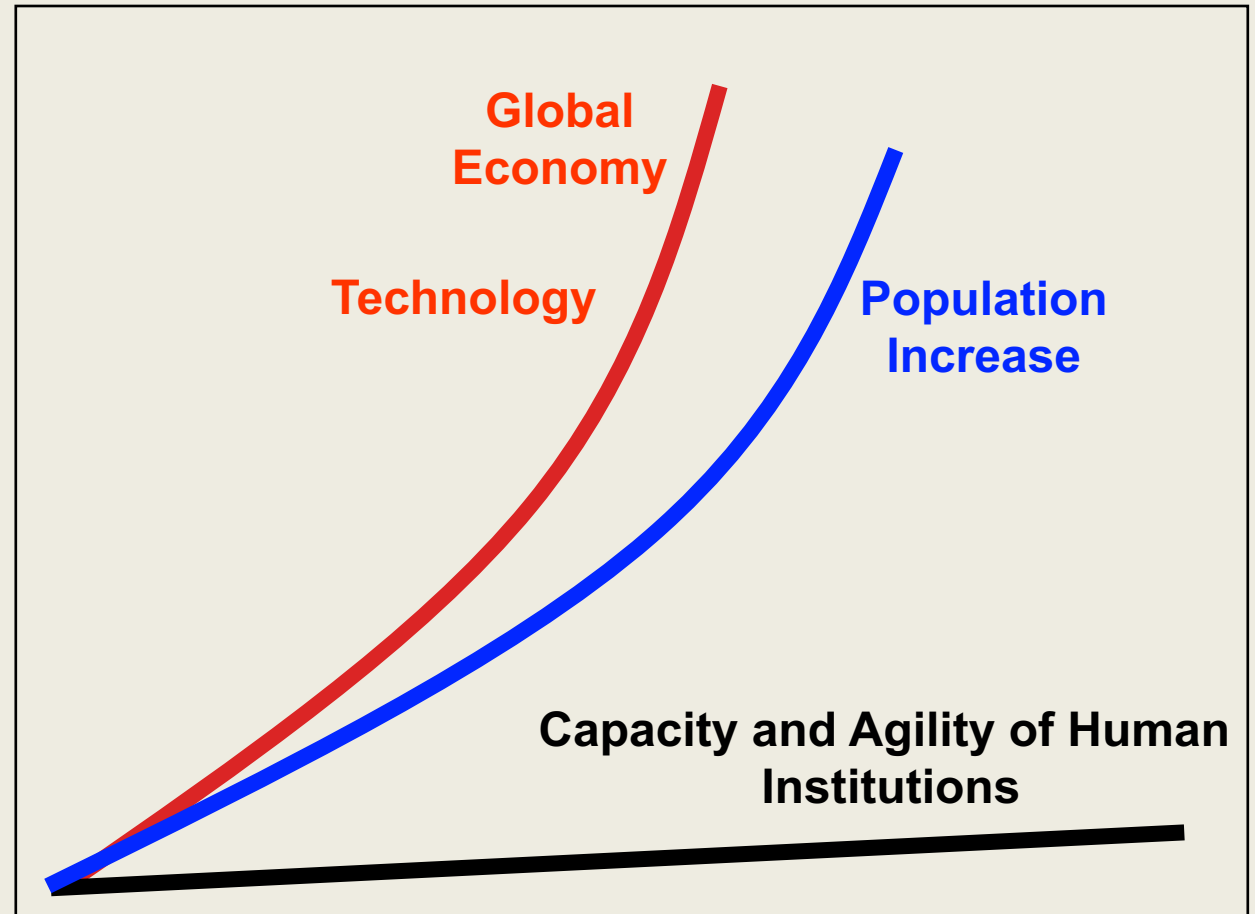


**Jean Francois Rischard  
(former VP, World Bank)**



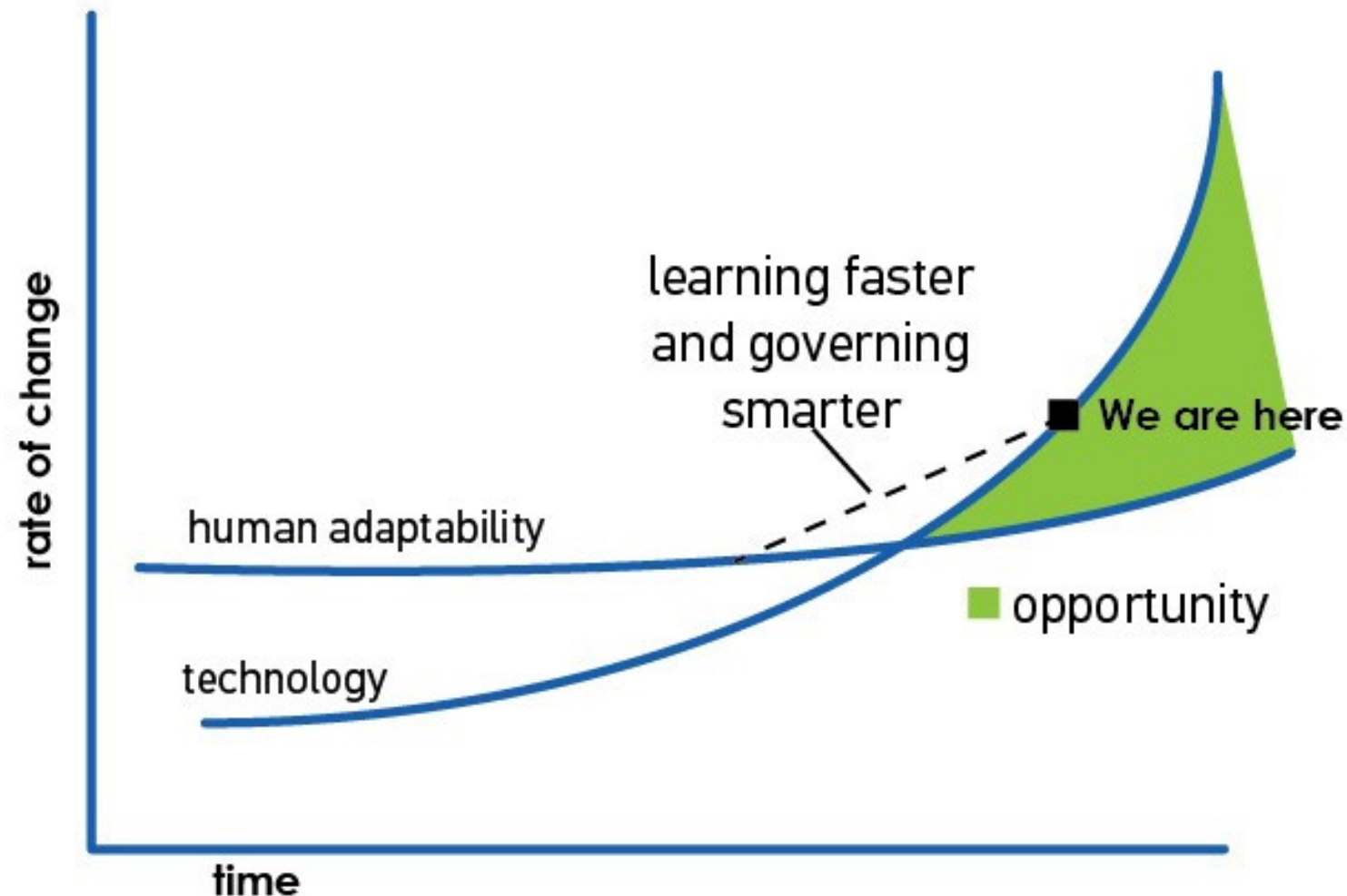
***“You can make a difference,  
you must make a difference.”***

**A Dangerous Gap . . .**



1970 book “Future Shock” by Alvin Toffler: Technology is changing too rapidly and humans simply can’t cope with it

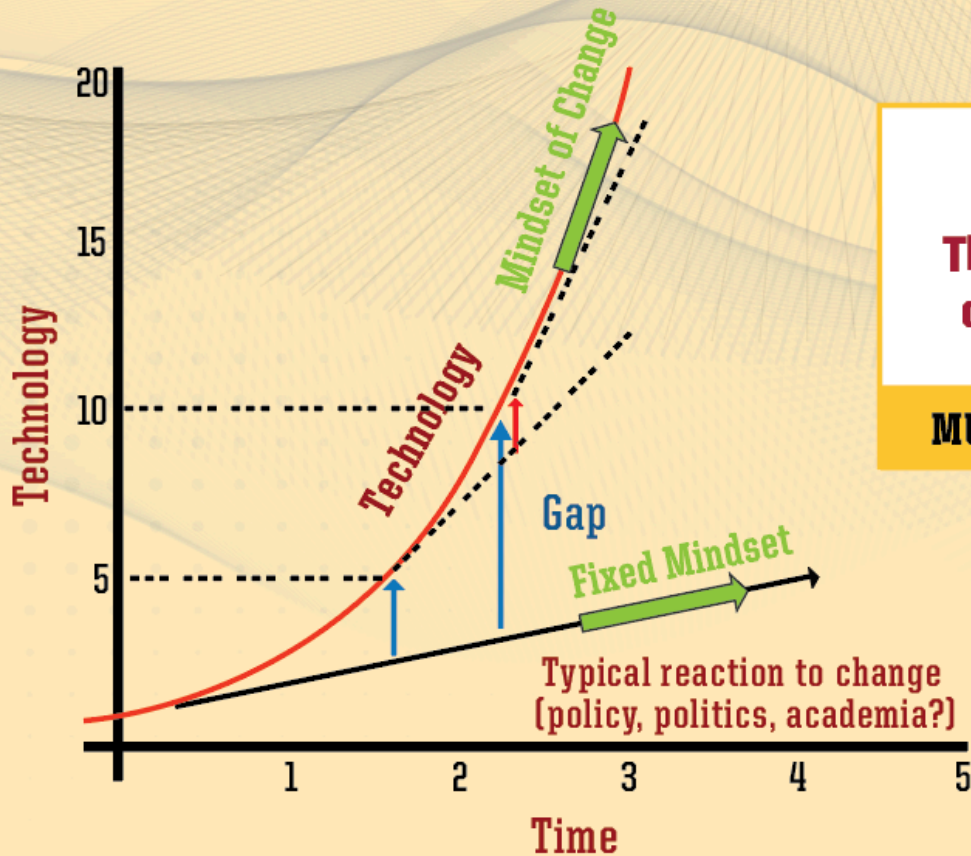
2016 book “Thank You for Being late” by Thomas Friedman: Technology is accelerating faster than our ability to adapt. But we can catch up





# Fast growing technology: Era of Constant Accelerations

**THE EXPONENTIAL PACE OF TECHNOLOGY BRINGS CONSTANT DISRUPTION.  
THIS REQUIRES AGILITY AND ADAPTABILITY - AND NEW MINDSETS**



**EXPONENTIAL CHANGES**  
There are no longer steady states  
or even steady states in growth

**MUST REINVENT OURSELVES EVERY YEAR**

*Exponential*, if the technology speed is proportional to it

$$\frac{\Delta A}{\Delta t} \approx \lambda A$$

Faster than exponential (*singularity*) if it is proportional to a higher power ( $n > 1$ )

$$\frac{\Delta A}{\Delta t} \approx \lambda A^n$$

# Exponential Technologies and Convergence Paths

**EUX**     *Engineering and X comingle*

***Where X is anything\*!***

Media, Medicine, Entertainment, Biology, Education, Sociology, Politics, Culture ...

E makes X “smarter”, more “efficient”

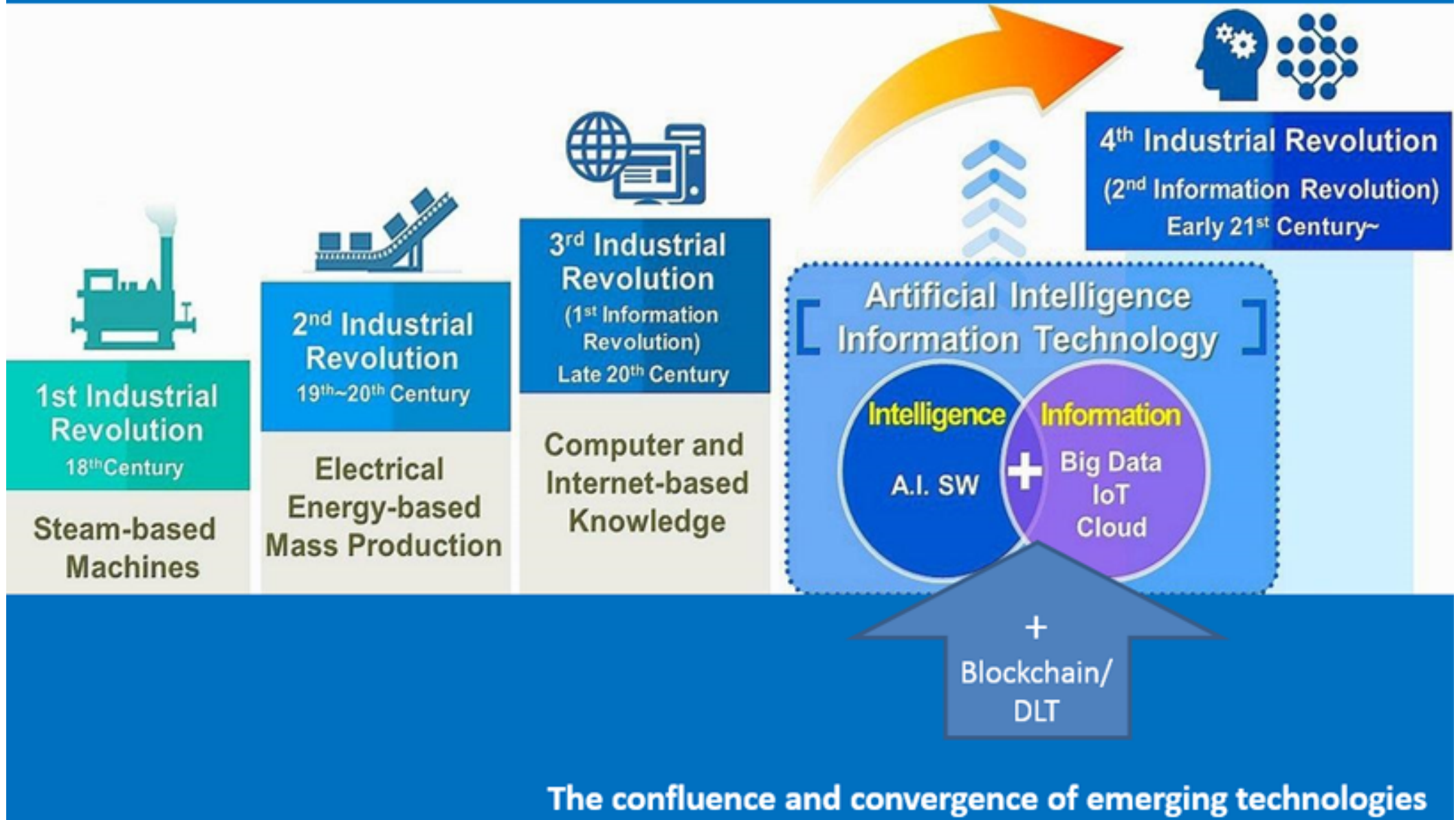
X: new phenomena/provide context creates new E

A “double helix” of E and X

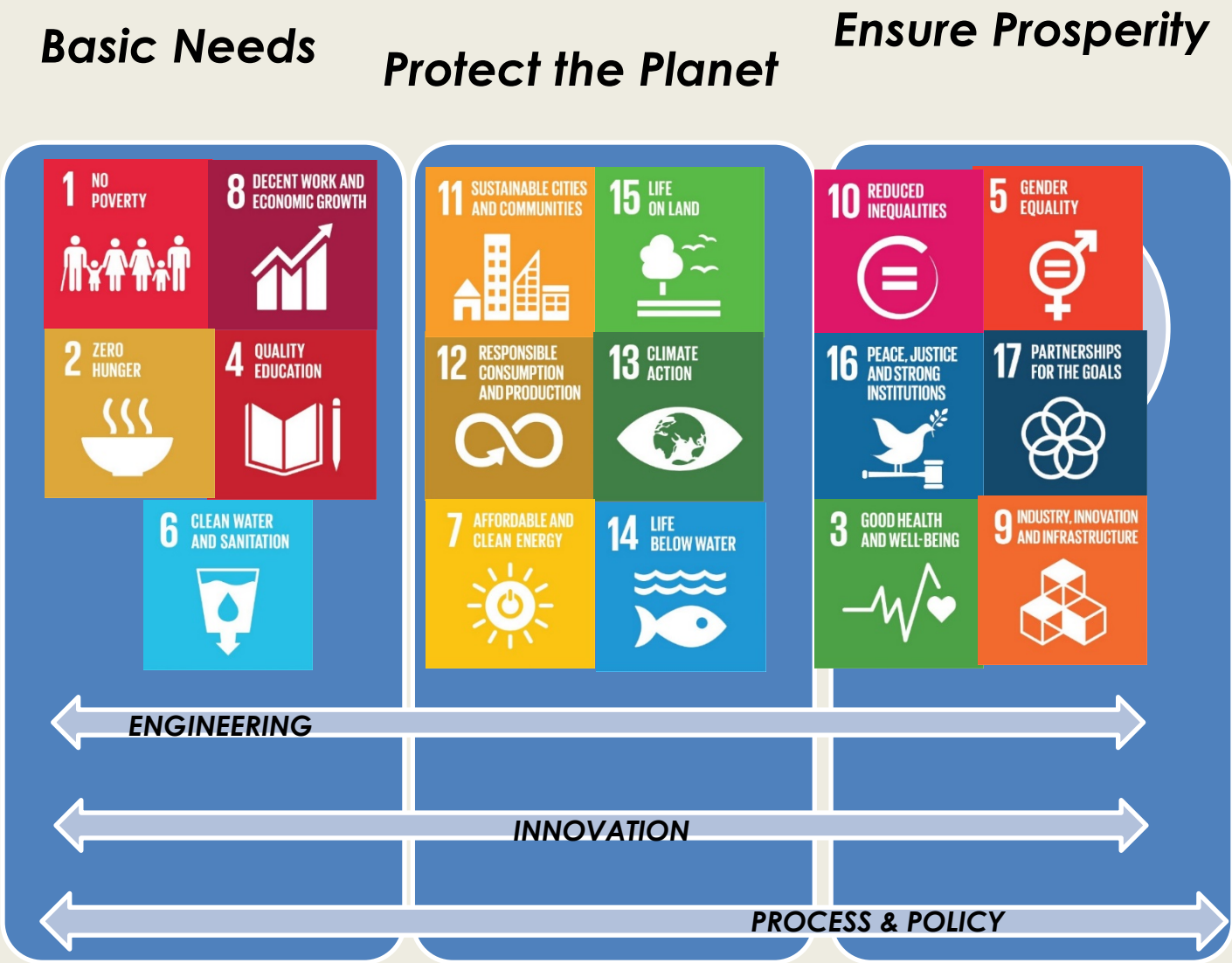
Exponential Technologies - Nano, Bio, Info, Communication, Cogno, Socio.....



# The Fourth Industrial Revolution



# Synergy between UN SDG's & Grand Challenges for Engineering



**ENABLERS: Engineering, Innovation & Policy**





NAE GRAND CHALLENGES  
FOR ENGINEERING



SUSTAINABLE  
DEVELOPMENT GOALS



## Sustainability

Energy  
Environment  
Global Warming



Security  
Reducing  
Vulnerability  
to Human and  
Natural Threats

## Health

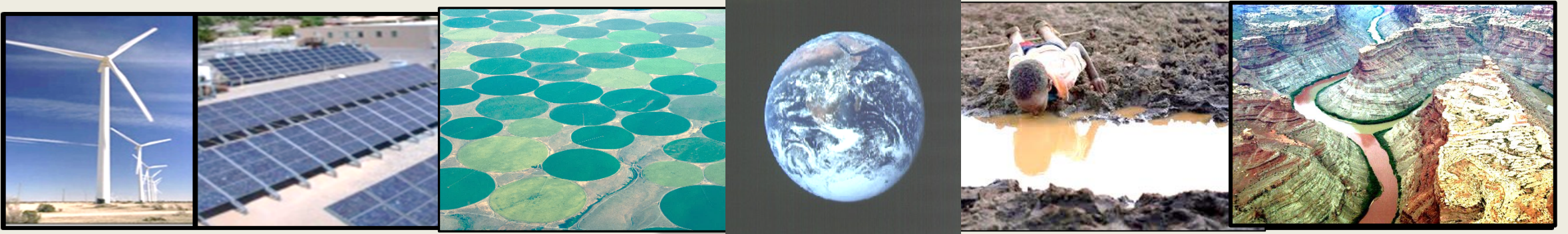
Improve Medicine and  
Healthcare Delivery



## Joy of Living

Expand and  
Enhance Human  
Capability





# Global Interdependencies and Trends

## The Nexus between Energy-Water-Food-Ecosystems

We are ALL in This Together

危机

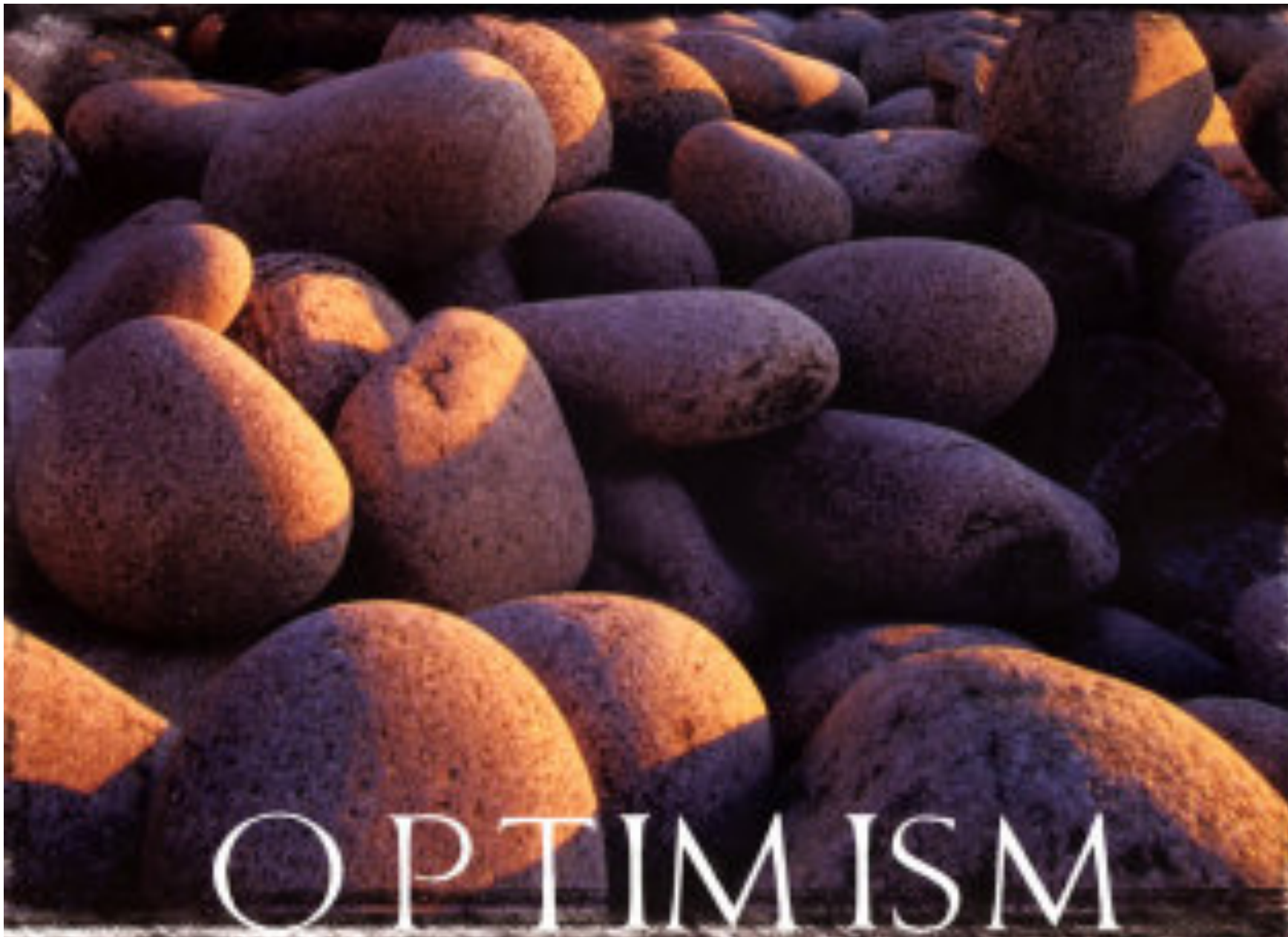
Wei-ji

## Challenges and Opportunities

**Creating the 21<sup>st</sup> Century Engineering Talent to  
Address Global Grand Challenges**

***GCSP model is Extremely Effective and Valuable  
as a mechanism for Creating the Workforce to  
Address ALL Grand Challenge-Like Initiatives***





*“The difference between stumbling blocks and stepping stones is how they are perceived.”*

Thank You!

Bramakrishna@NAE.edu