



THE PROMISE AND CHALLENGES OF CONVERGENT RESEARCH

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Informed by:

Dean of Engineering- 2005-present

NRC CERC Report Contributor- 2015-2017

NRC SBE Report Contributor- 2017

NAE Grand Challenges Scholars Program 2009- present

NAE Council- 2017-present

ASEE Diversity Initiative- 2005-present

NSF I-Corps Node Los Angeles PI- 2015-present

Accelerating Engineering Research Center Preparedness Workshop
October 2-3, 2018 Crystal City Hyatt Regency, Arlington, VA



WHY CONVERGENCE?

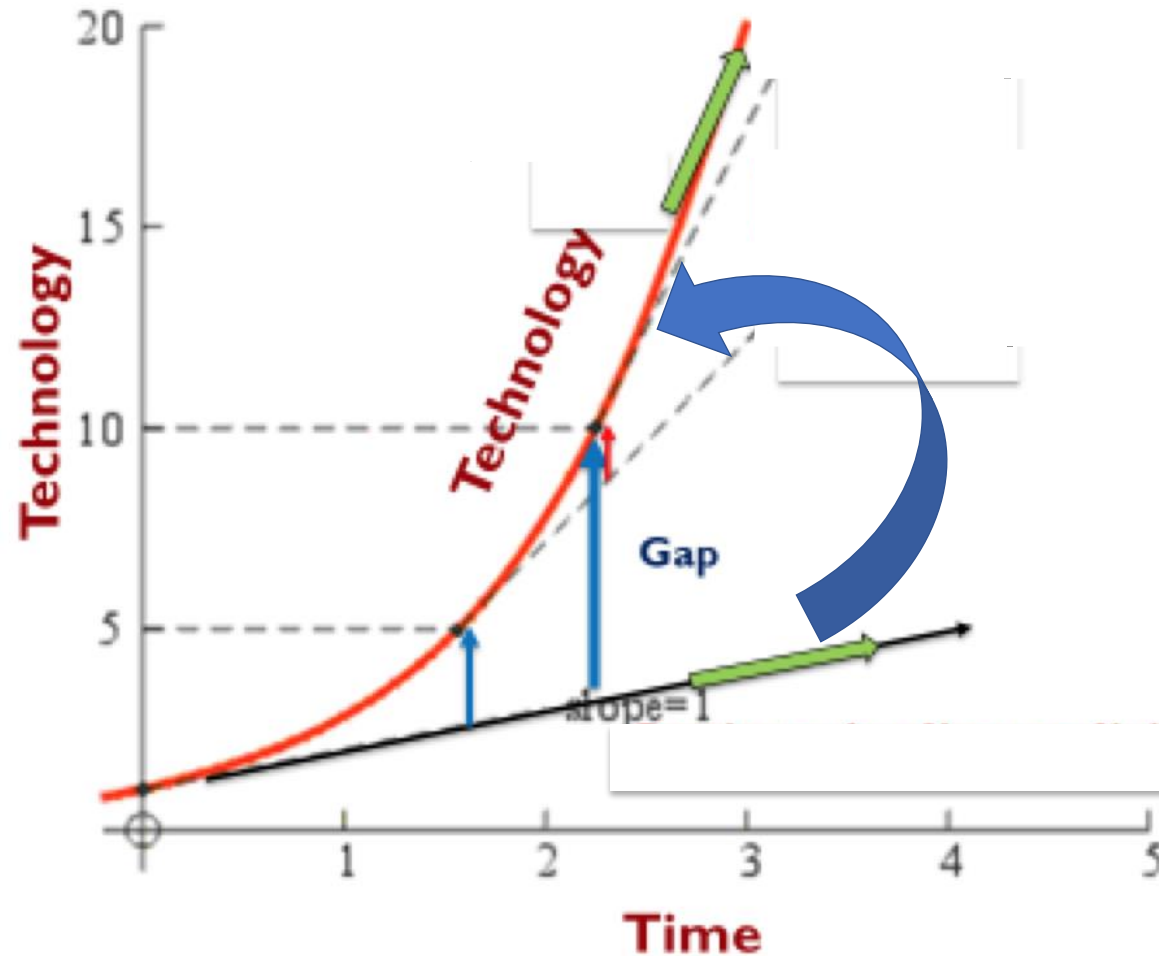
Exponential Technology

*Era of Constant Accelerations**

**Friedman (2016)*



No steady states
No steady states in growth



Immense Opportunities
Solving Big Problems
Disruption



LINEAR KINETICS: $A \rightarrow A$

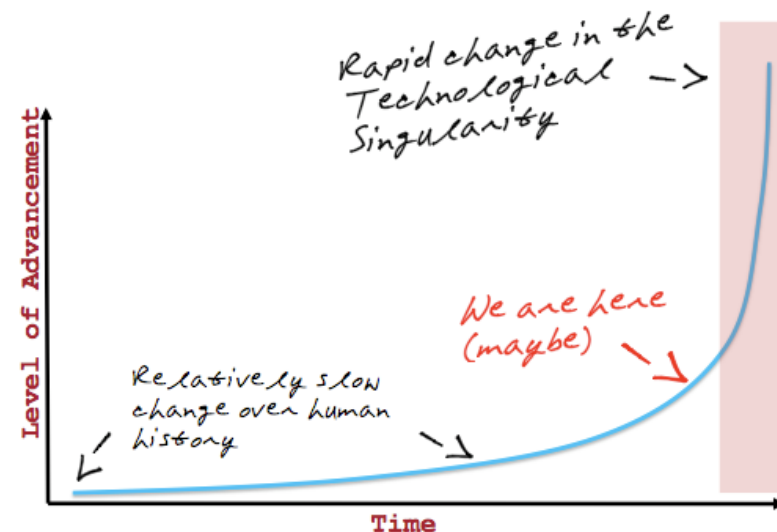
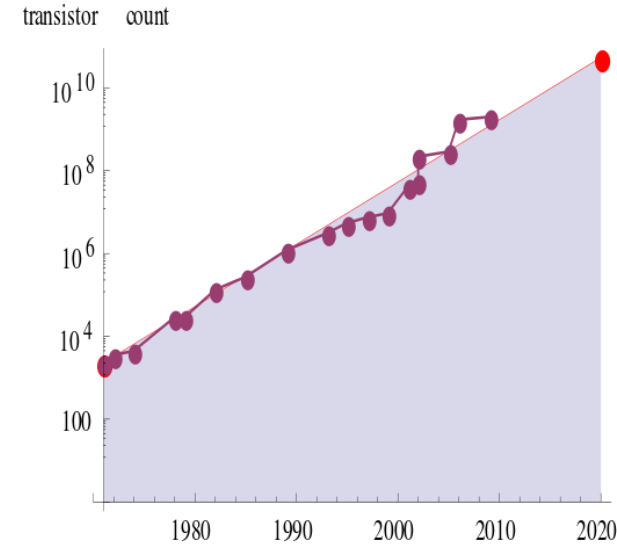
$$\frac{\Delta A}{\Delta t} \approx \lambda A \Rightarrow A \approx A_0 \exp(\lambda t)$$

EXPONENTIAL INCREASE: **MOORE'S LAW!**

QUADRATIC KINETICS: $A + A \rightarrow 2A$

$$\frac{\Delta A}{\Delta t} \approx \lambda A^2 \Rightarrow A \propto \frac{1}{(t^* - t)}$$

SINGULARITY AT t^*
KURZWEIL'S CONJECTURE?



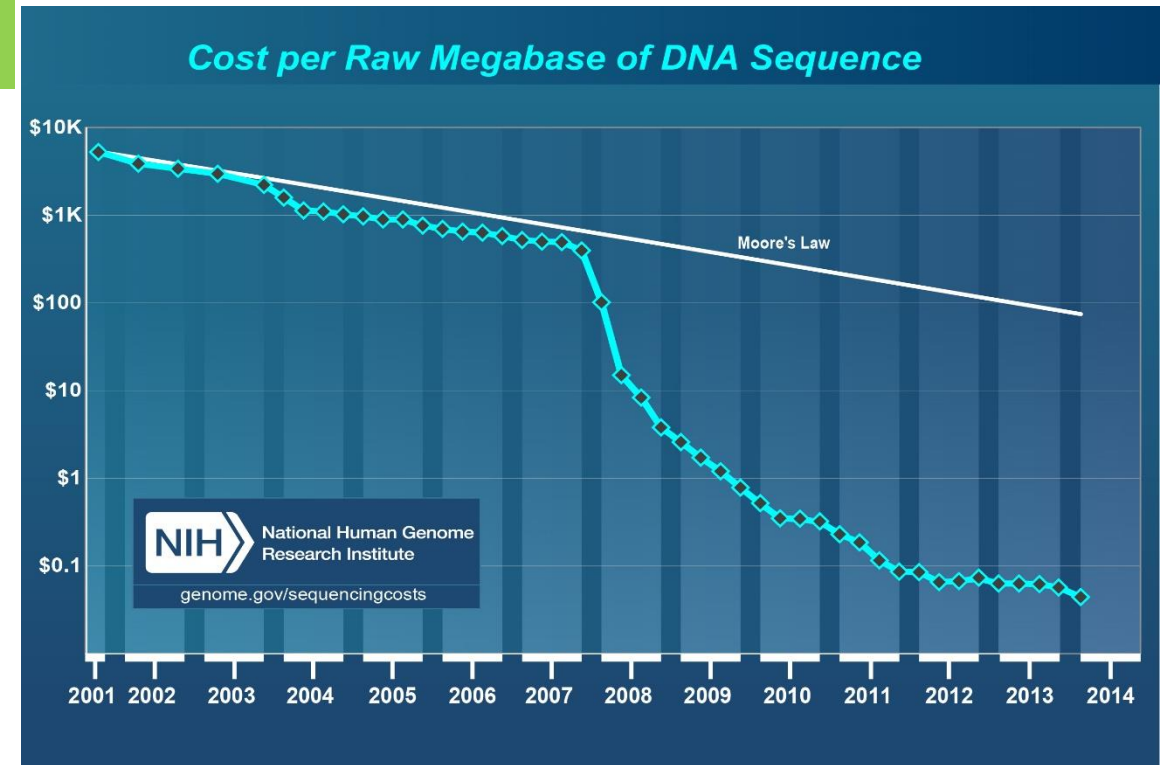


NON-LINEAR: $nA \rightarrow B$

$$\frac{\Delta B}{\Delta t} \approx \lambda A^n \implies B \approx B_0 \exp(n\lambda t)$$

EXPONENTIAL INCREASE
WITH A DIFFERENT
EXPONENT

(A= INFORMATION
TECHNOLOGY; B=
BIOTECHNOLOGY?)





WHY ENGINEERING?

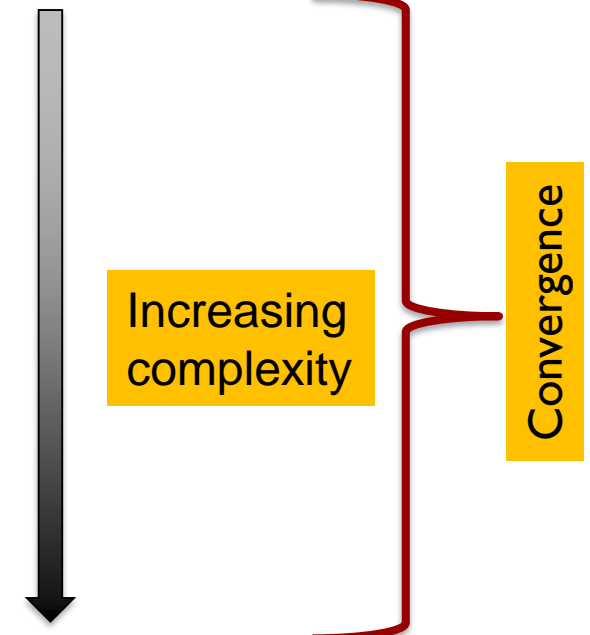
*Enabling Discipline of Our Times
(Exponentially Growing)*

*Human Nature does not Change
Exponentially Fast!*

TECHNOLOGY

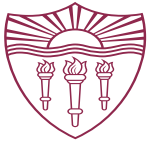
LEVERAGING *PHENOMENA** FOR *USEFUL PURPOSES***

- **PHYSICAL** (e.g. Photoelectric Effect)
- **CHEMICAL** (e.g. Catalysis)
- ◎ **GEOLOGICAL** (e.g. groundwater)
- ◉ **BIOLOGICAL** (e.g. Bioengineering)
- ***SOCIAL-BEHAVIORAL***



Paraphrased from
Brian Arthur (2008)

*And systems, devices and tools- and combinations thereof
**Including the discovering of new phenomena



ENGINEERING + X

Where X is anything!

E.g. Media, Medicine, Entertainment, Biology, Education,...

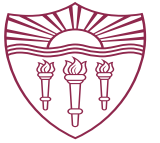
Three pathways:

E²X (Engineering Empowers X)

X²E (X empowers Engineering)

EUX (Engineering and X comingle)

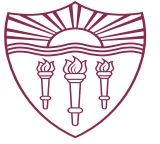
E and X can be vectors



E2X

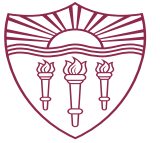
ENGINEERING EMPOWERS X

E makes X “smarter”; more “efficient”;
opens new dimensions, many disruptive.
It is also the ubiquitous digitization of everything
(Digital Technologies)



X2E *X EMPOWERS E*

We will call it X-mimetic
Biomimetic: Nature's optimization through evolution
Perhaps other



EX

ENGINEERING AND X COMINGLE

E makes X “smarter”, more “efficient”

X: new phenomena/provide context. which create new E.

A “double helix” of E and X

Nanotechnology, Biotechnology, Cognitive, etc.

(Exponential Technologies)

Likely the subject of a CERC



- Increasing **complexity** addressed by exponentially advancing technology
- This allows tackling **Grand-Challenge-like** problems
- Convergence of disciplines, but also web of **partnerships**
- (Powerful technology brings powerful **unintended consequences** (ethics, societal))

 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 health 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	







SUSTAINABILITY

Make Solar Energy Economical, Provide Energy from Fusion, Develop Carbon Sequestration Methods, Manage the Nitrogen Cycle, Provide Access to Clean Water



SECURITY

Secure Cyberspace, Prevent Nuclear Terror, Restore and Improve Urban Infrastructure



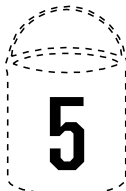
HEALTH

Engineer Better Medicines, Advance Health Informatics, Reverse Engineer the Brain



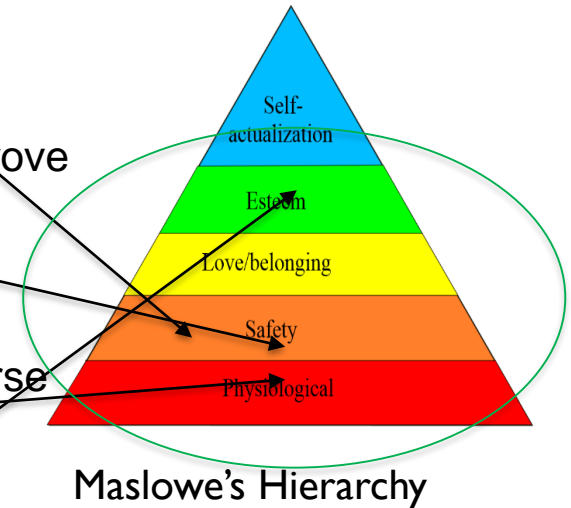
ENRICHING LIFE

Enhance Virtual Reality, Advance Personalized Learning, Engineer the Tools of Scientific Discovery



SOCIETAL ORGANIZATION?

Social Phenomena (Through cyberphysical and data science)





Individual and family well-being

- Ensure healthy development for all youth
- Close the health gap
- Stop family violence
- Advance long and productive lives



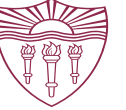
Stronger social fabric

- Eradicate social isolation
- End homelessness
- Create social responses to a changing environment
- Harness technology for social good

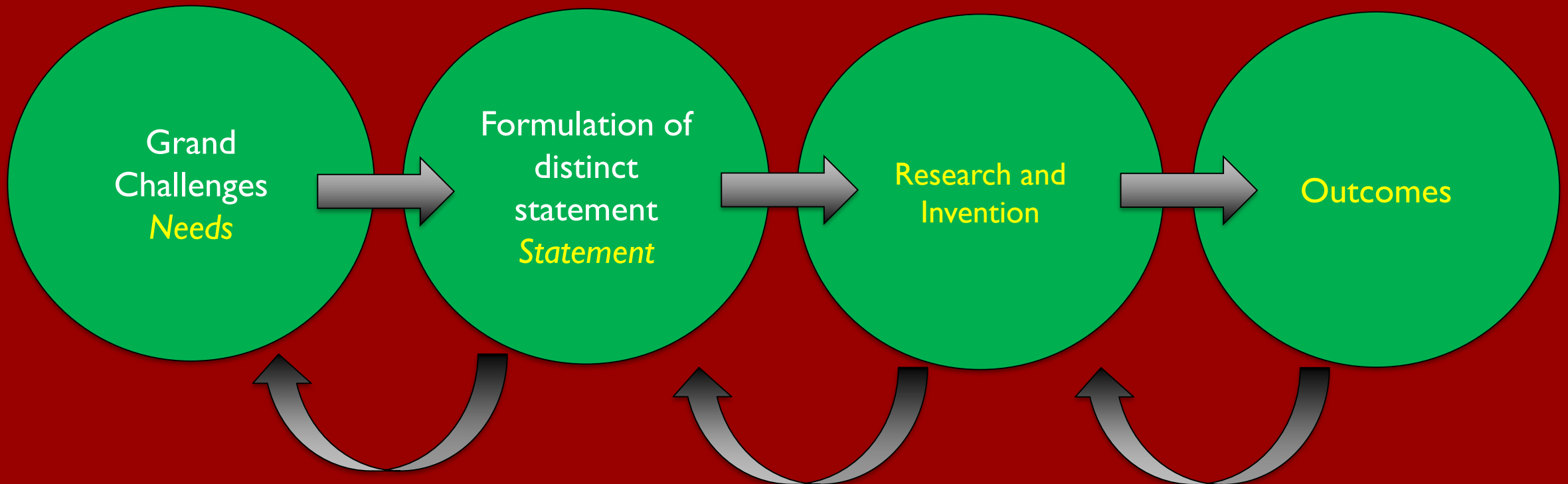


Just society

- Promote smart decarceration
- Build financial capability for all
- Reduce extreme economic inequality
- Achieve equal opportunity and justice

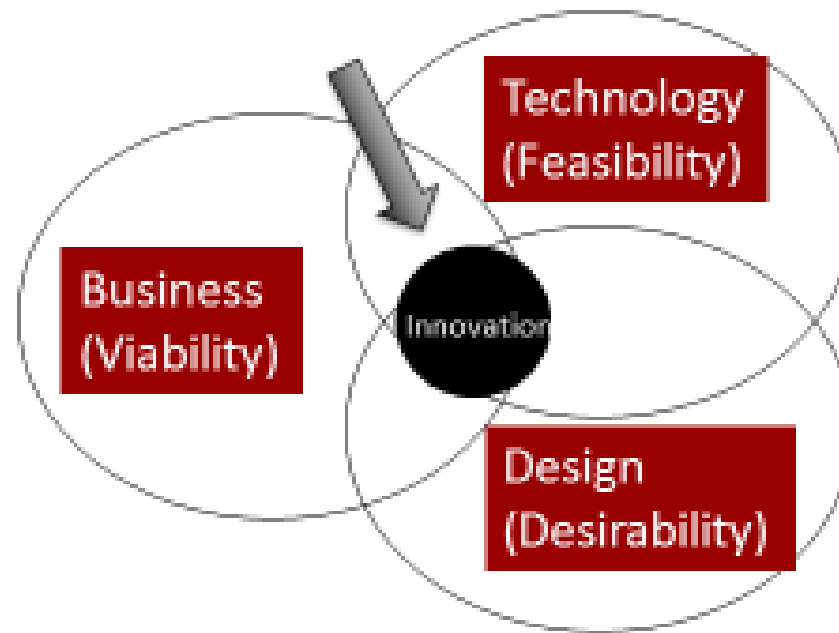


Addressing the solution of Grand Challenge-like problems parallels innovation methodologies (e.g. Stanford BioDesign)





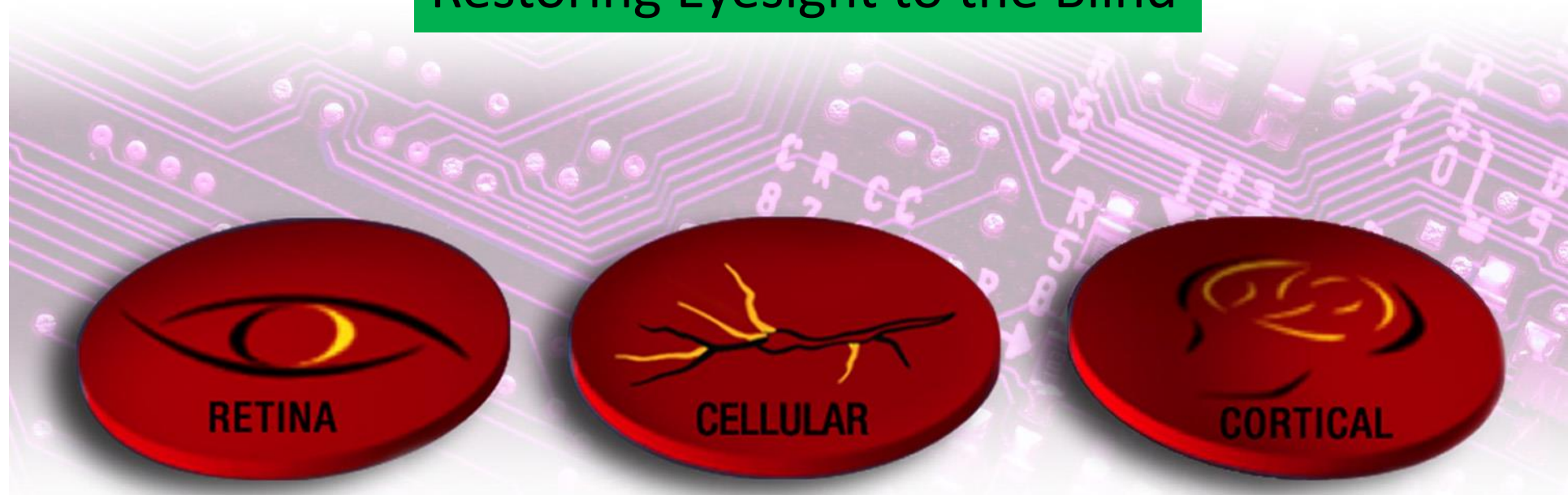
INNOVATION IS INTRINSICALLY CONVERGENCE



(Expired) BMES ERC: Engineering + Ophthalmology

Restoring Eyesight to the Blind

Need



Statement

Biomimetic microelectronic systems will form direct high-density interfaces with the human nervous system to restore lost function



Need: Solve the Grand Challenge of Personalized Learning

Statement: Maximize learning tailored to the individual; Restore lost learning functions in individuals with TBI or neurological diseases;

Invention: Apply or adapt existing technologies (e.g. wearables and other IoT cyberphysical sensors); Next-generation distance and interactive teaching and learning, new educational technologies (ML, AI, Analytics); Understand how humans learn; New information-processing technologies, such as neuromorphic computing; New convergent systems, such as cyber–neural systems (a counterpart to cyberphysical systems).

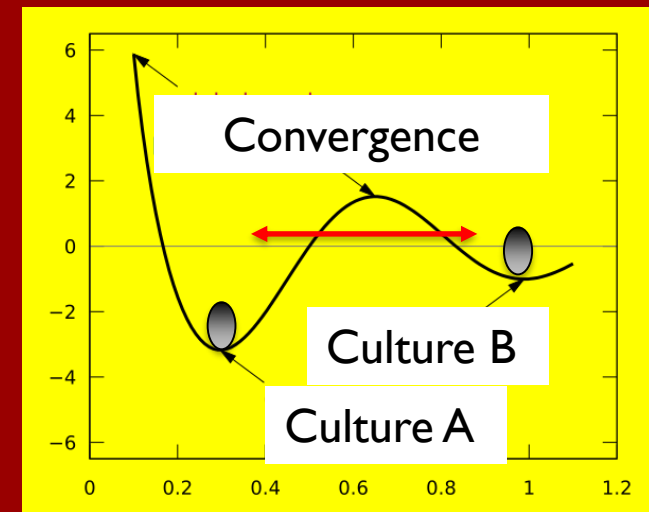
Outcomes: Advance personalized learning; new advances in ML and AI; Democratize access to education at all levels; Strengthen individual decision making by eliminating implicit or anchor biases; Create a more equitable and informed global society; Improved communication messages, from advertising to marketing.

Team: Computer scientists; electrical, biomedical, biochemical, and neuro engineers; education researchers and teachers; neuroscientists and psychologists; social scientists; ethicists; communication and entertainment experts.

CONVERGENCE CHALLENGES

“Culture wants to be enduring and prevailing”

from Antonio Damasio’s “The strange world of things” (2018)





1. Talent: students, faculty, staff- and environment to flourish

PEOPLE

2. Value: Continuously adding value to curriculum, programs

PROGRAMS

3. Thought Leadership: Research and discovery

PAPERS

4. Impact: Impact on society and the economy (Innovation and Entrepreneurship)

PRACTICES-PATENTS



CHANGING THE CONVERSATION FOR AN EXPONENTIALLY CHANGING WORLD:

What we do

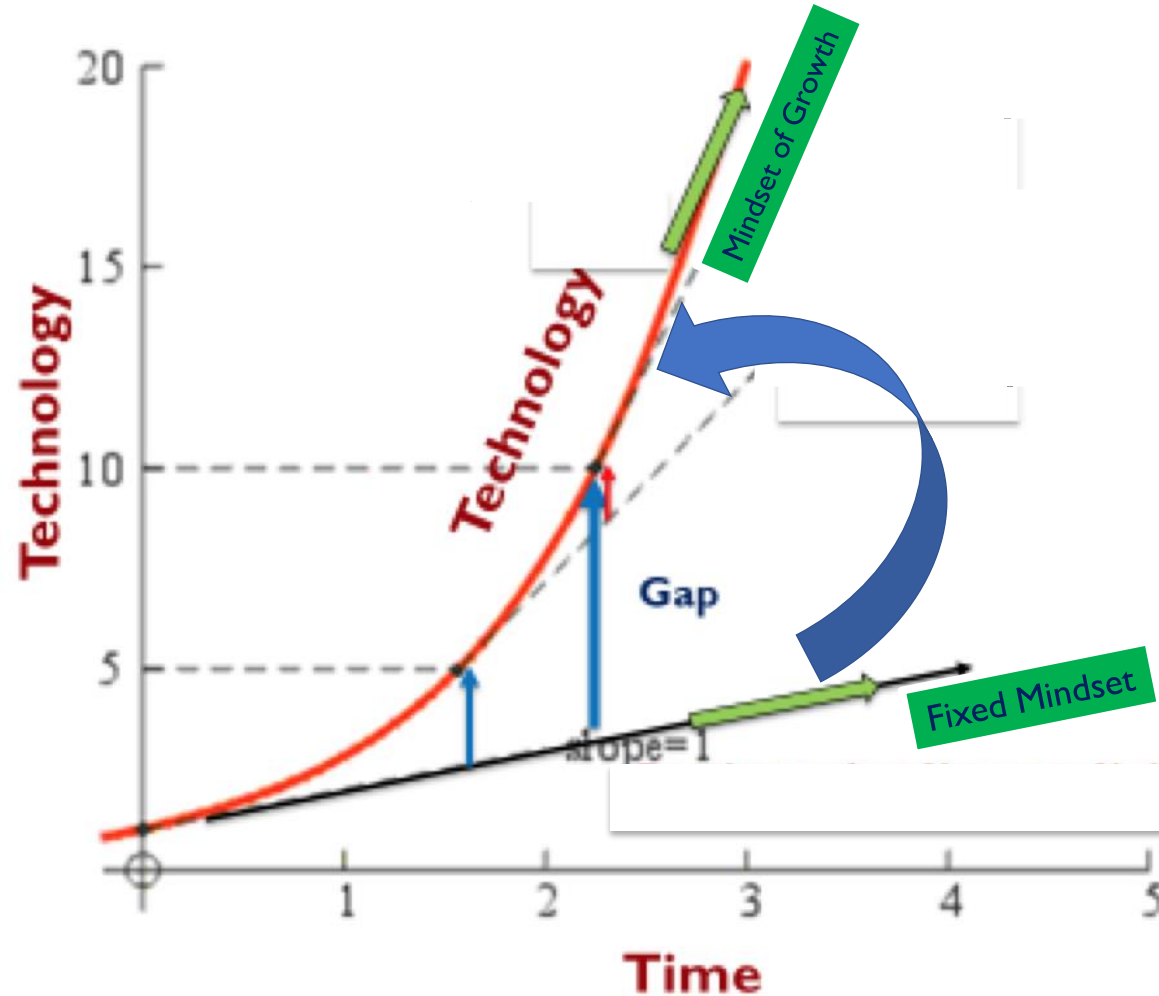
Who we are

What we look like- and

How we reinvent ourselves



Agility, adaptability And new mindsets

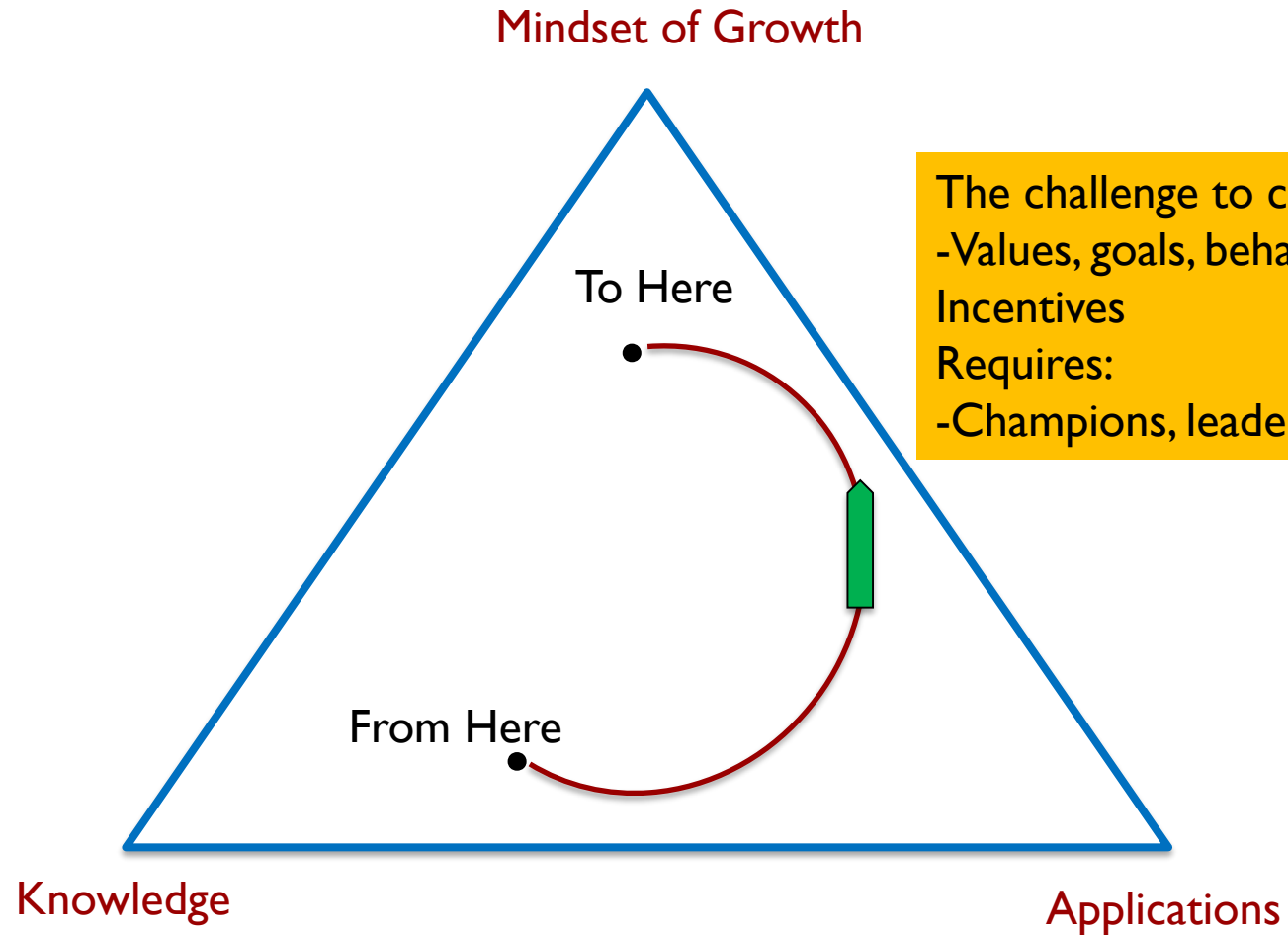




THE FIVE MINDSETS OF CHANGE TO THRIVE IN TODAY'S WORLD

- 1 HUG THE EXPONENTIAL**
Superb Technical Skills and Knowledge to Lead the Exponentially Changing Technology
- 2 ENGINEERING +: CHANGE THE CONVERSATION ABOUT ENGINEERING**
Engineering + X where X is anything (particularly, human-centric)
Who we are, what we do and what we look like.
- 3 INNOVATION IN THE BROADEST SENSE**
Innovation and Entrepreneurship, to help create the new markets,
the new jobs and to design the new self.
- 4 THE CULTURAL MIND**
Cultural Awareness (with culture broadly interpreted), to help thrive in
today's fast changing world.
- 5 HEROIC ENGINEERING**
Awareness of the Impact of Engineering to Society
(and the importance of technology ethics).

Re-new and
Re-assess



The challenge to change culture:
-Values, goals, behavior, attitude, rewards and Incentives
Requires:
-Champions, leadership, mindsets of growth



Conceived in 2009 (USC, Duke, Olin):
Adopted by > 80 schools nationwide: Supported by the
NAE

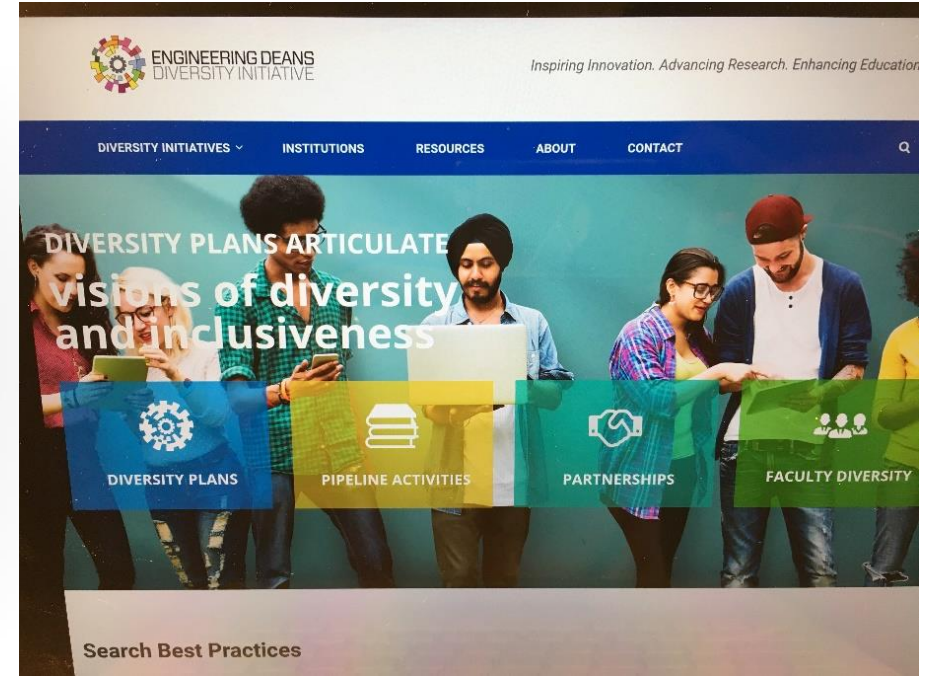
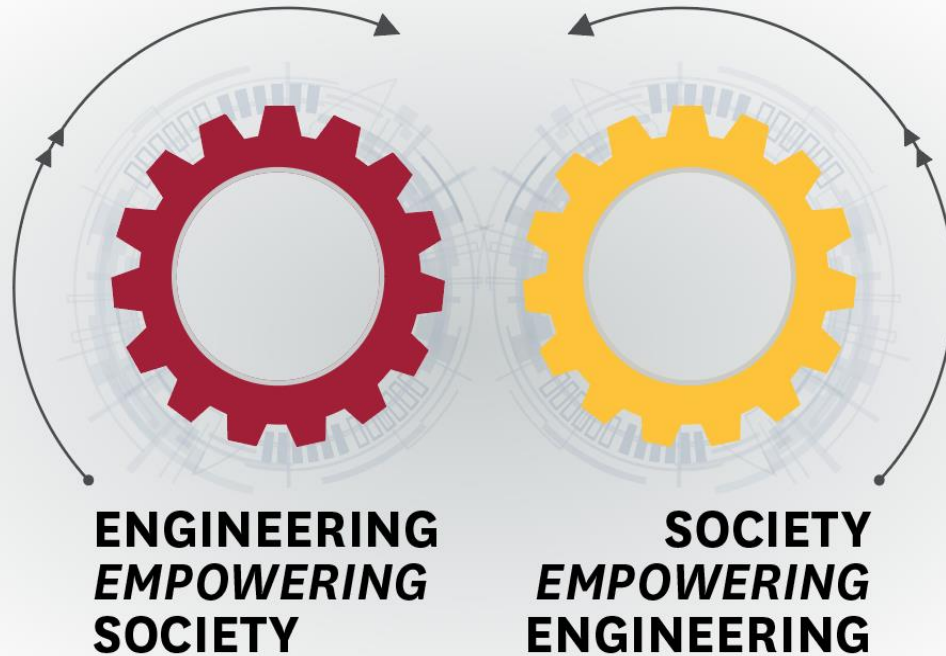
Consistent with WEF report on added skills for the 21st century:
Creativity, Leadership, Perseverance
Consistent with the *Engineer of 2020*

CULTIVATES FIVE MINDSETS

- 1. Research/creative**
- 2. Multidisciplinary**
- 3. Entrepreneurial**
- 4. Cultural**
- 5. Society conscious**





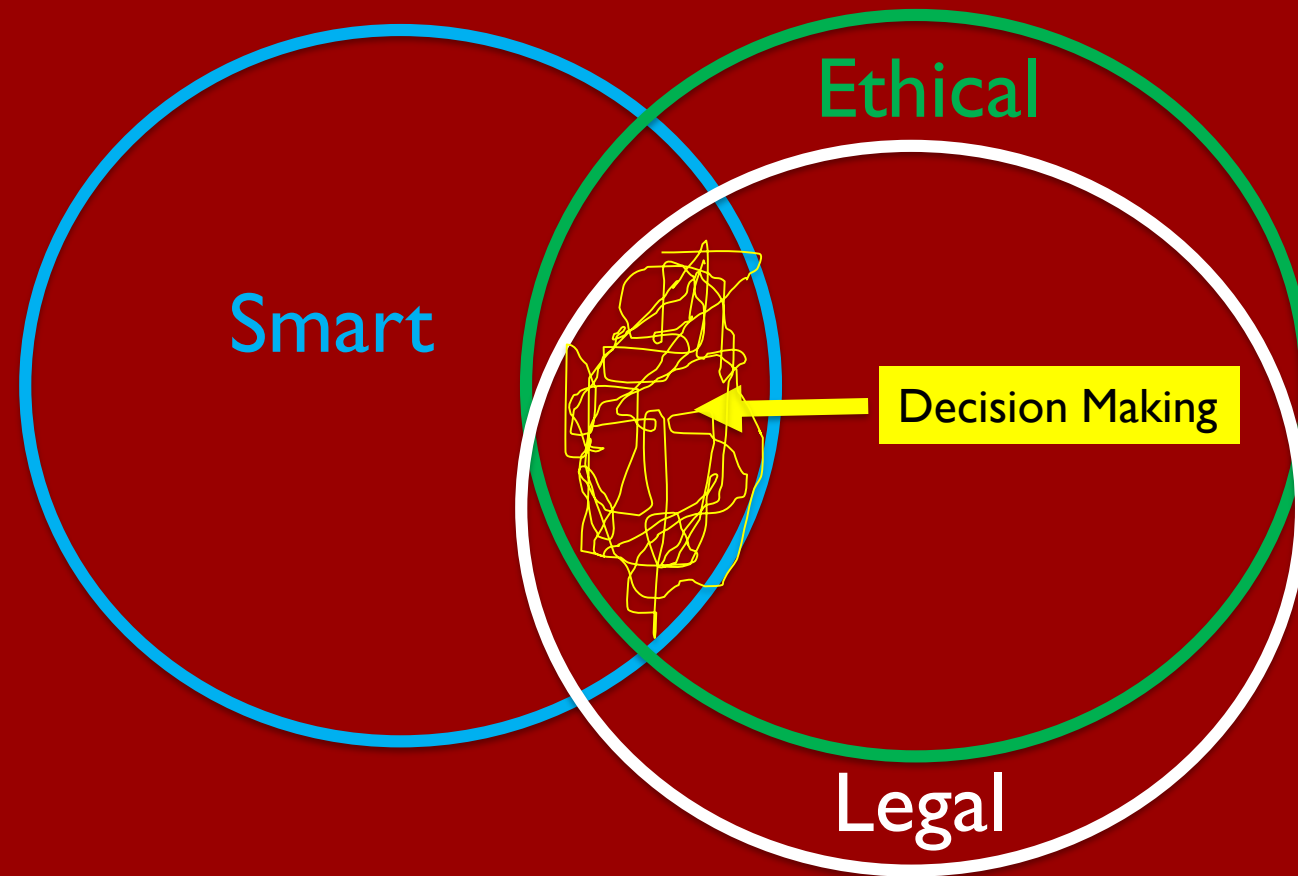


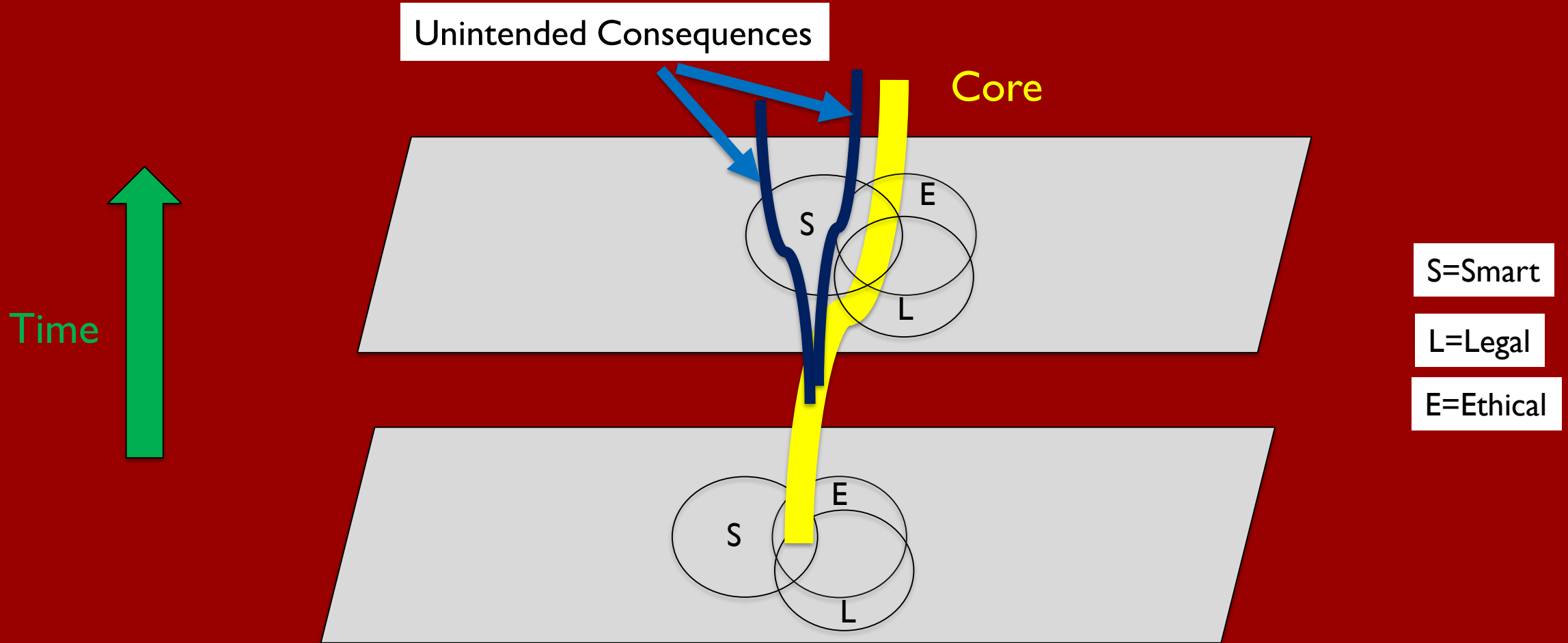
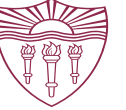
**NATIONAL (ASEE) DIVERSITY AND INCLUSION
INITIATIVE (NOW SIGNED BY 210+ SCHOOLS
NATIONALLY)**



USEFUL LINKS PHENOMENA WITH **LEVERAGING**

- **ETHICAL-LEGAL**
- **UNINTENDED CONSEQUENCES**
- **COMPLEXITY**
- **POLICY- LEGISLATION- REGULATION**





Unintended consequences will always be there because of our complex, non-linear world.



1. Hug the Exponential
2. Engineering +
3. Innovation in the Broadest sense
4. The Cultural Mind
5. Heroic Engineering



- Problems are inevitable
- All Problems are solvable

(From David Deutsch's book "The beginning of infinity")

