



# Engineering in the Era of Convergence

*The 4th Industrial Revolution:*

Convergence

*of physical, chemical, biological, behavioral  
and social phenomena*



# TECHNOLOGY: EXPLOITING A *PHENOMENON*\* FOR *USEFUL* PURPOSES

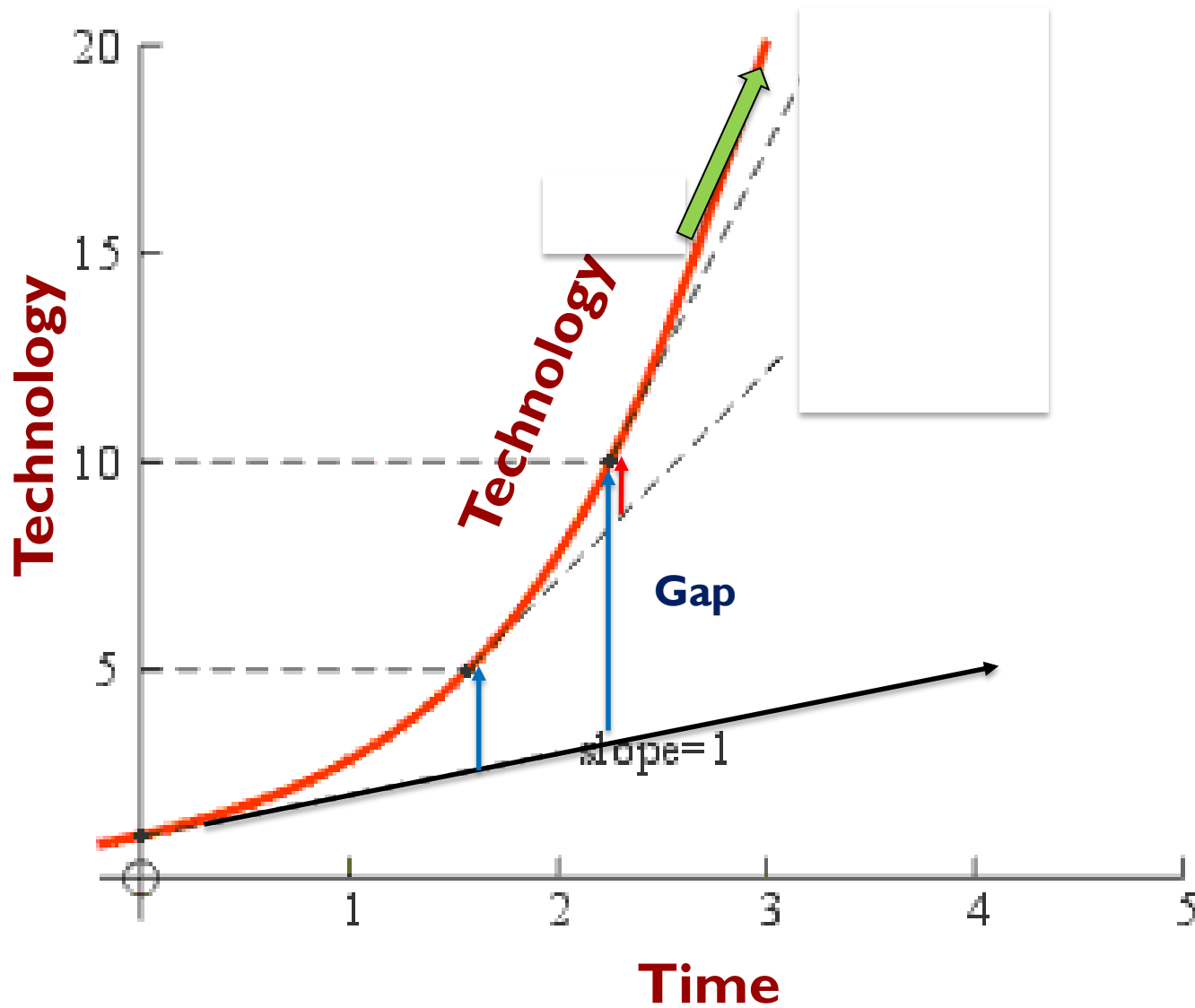
- **PHYSICAL** (e.g. Photoelectric Effect)
- ◉ **CHEMICAL** (e.g. Catalysis)
- ◎ ***GEOLOGICAL*** (e.g. *petroleum*)
- ◉ **BIOLOGICAL** (e.g. Brain Imaging)
- ◉ ***SOCIAL-BEHAVIORAL***



Increasing complexity

\*And combinations of phenomena or technologies

\*\*Including the discovering of new phenomena





LINEAR KINETICS:  $A \rightarrow A$

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

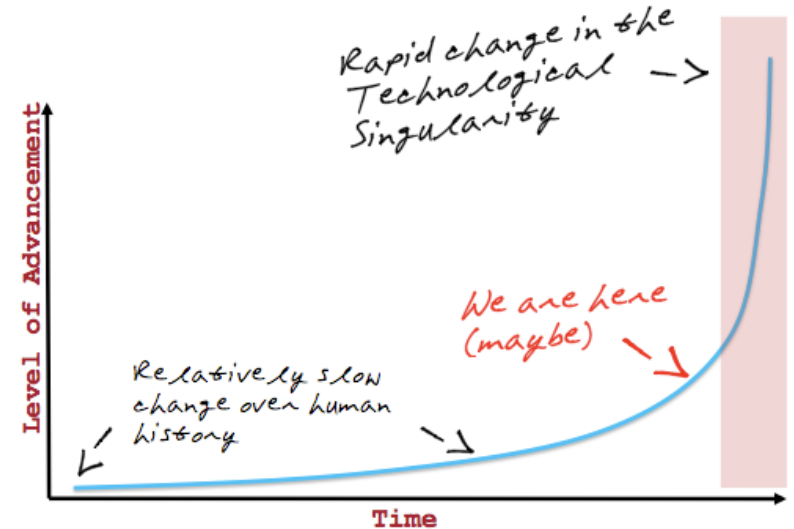
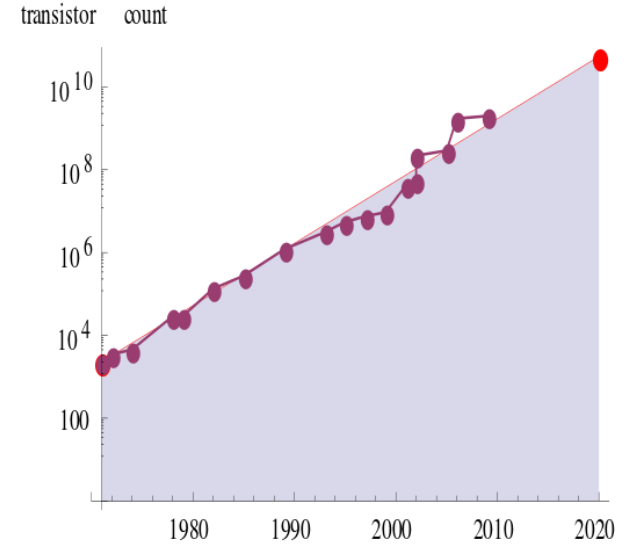
EXPONENTIAL INCREASE: **MOORE'S LAW!**

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**





**Digital Technologies:** where digitization is the key enabler for everything. It is the domains of computer science, big data, informatics. It defines the digital world as the new language to interpreting even experiencing our physical world- in a way it is the new mathematics.

**Combinatorial Technologies:** which borrow from existing ones to create new technologies. Where the main innovation is the idea and tools to combine, rather than discover, specific existing technologies for a useful purpose.

**Exponential Technologies:** such as nano-technology, or bio-technology. These require advanced, PhD- level research, with the promise of exponential pace returns.

(From Erik Brynjolfsson and Andrew McAfee's  
**"The Second Machine Age"**)



## TECHNOLOGY: EXPLOITING A PHENOMENON FOR *USEFUL PURPOSES\**

- ETHICAL-MORAL
- UNINTENDED CONSEQUENCES
- COMPLEXITY
- POLICY



# ENGINEERING + X

***Where X is anything!***

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

Three pathways: E2X, X2E, EUX

E2X (Engineering Empowers X)

X2E (X empowers Engineering)

EUX (Engineering and X comingle)

**Note: E and X can be vectors (multidisciplinarity)**



# E2X

## ***ENGINEERING EMPOWERS X***

E makes X “smarter”; more “efficient”;  
opens vast new dimensions, many disruptive (e.g.  
sharing economy- “uberization”).

It is also the ubiquitous digitization of everything  
(Digital Technologies)

CS, Machine Learning, Big Data, Cyber-Physical  
(PS: What if X is societal or human-centric?)





# X2E

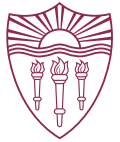
## ***CAN X EMPOWER E?***

We will call it X-mimetic

Biomimetic: Nature's optimization over evolution

Perhaps other

***(PS: What if X is societal or human-centric?)***



# EUX

## **ENGINEERING AND X COMINGLE**

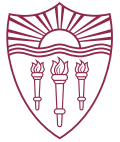
E makes X “smarter”; more “efficient”.

X discovers new phenomena which create new E.

A “double helix” of E and X.

Nanotechnology, Biotechnology, Cognitive, Social  
Sciences

(Exponential Technologies)



*What if X is human or society-centric?*

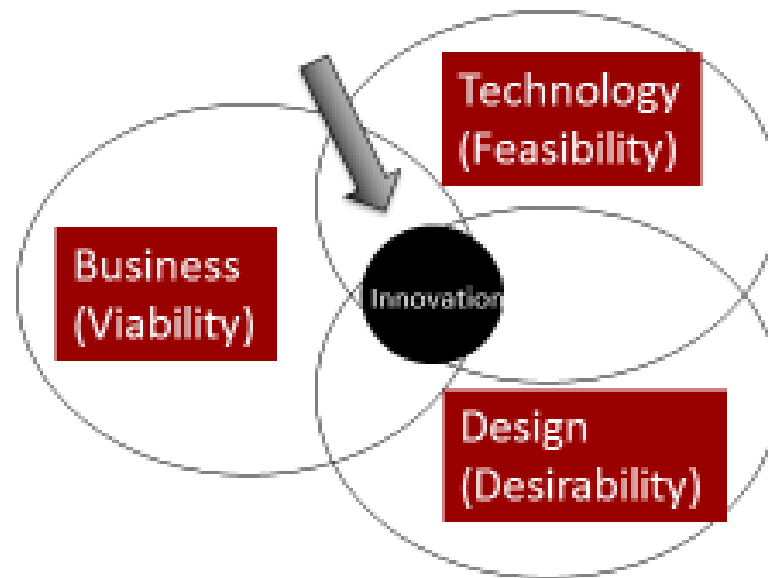
**E2X:** more “efficient”; better communication; e.g.  
social media.

**X2E:** Ethical decision making by autonomous  
systems- drones, driverless cars; e.g.  
AI for Social Good.

**EUX:** HMI (human-machine interaction)  
HBI (human-building interaction),  
any business and organization



## INNOVATION IS INTRINSICALLY CONVERGENCE





**Technology now allows us to  
solve**

**Grand-Challenge-Like**

**problems**



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

sustainability

Engineer Better Medicines  
Advance Health Informatics  
Reverse Engineer the Brain

health

Secure Cyberspace  
Prevent Nuclear Terror  
Restore and Improve Urban Infrastructure

security

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

enriching life





## 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



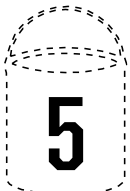
## HEALTH

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



## ENRICHING LIFE

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

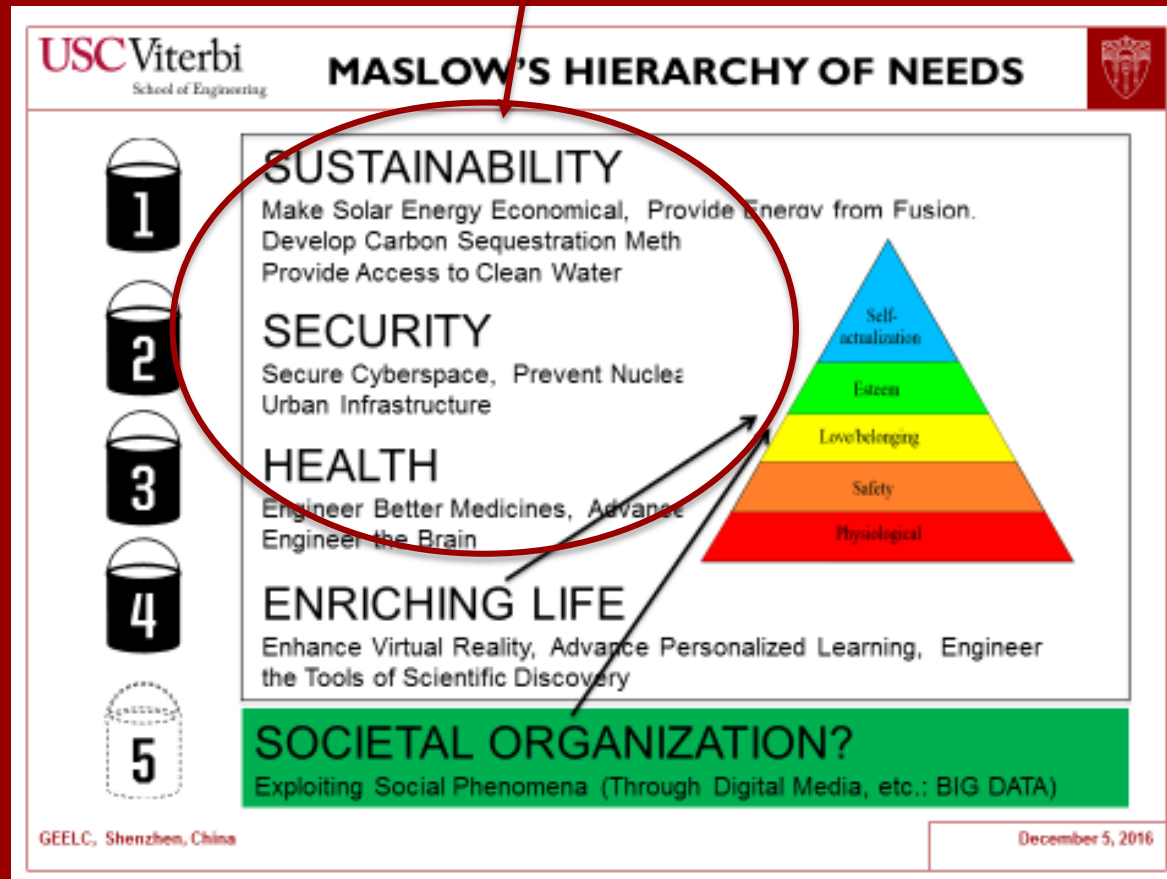


## SOCIETAL ORGANIZATION?

Social Phenomena (Through Digital Media and other: BIG DATA)



Convergence of *physical, chemical, biological, behavioral and social* phenomena: Address the fundamental needs in Maslow's hierarchy



*In order to be able to further enrich life*





## *Individual and family well-being*

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



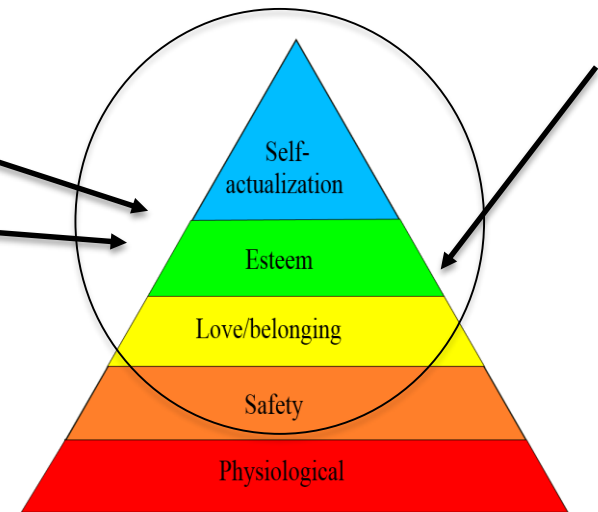
## *Stronger social fabric*

- 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

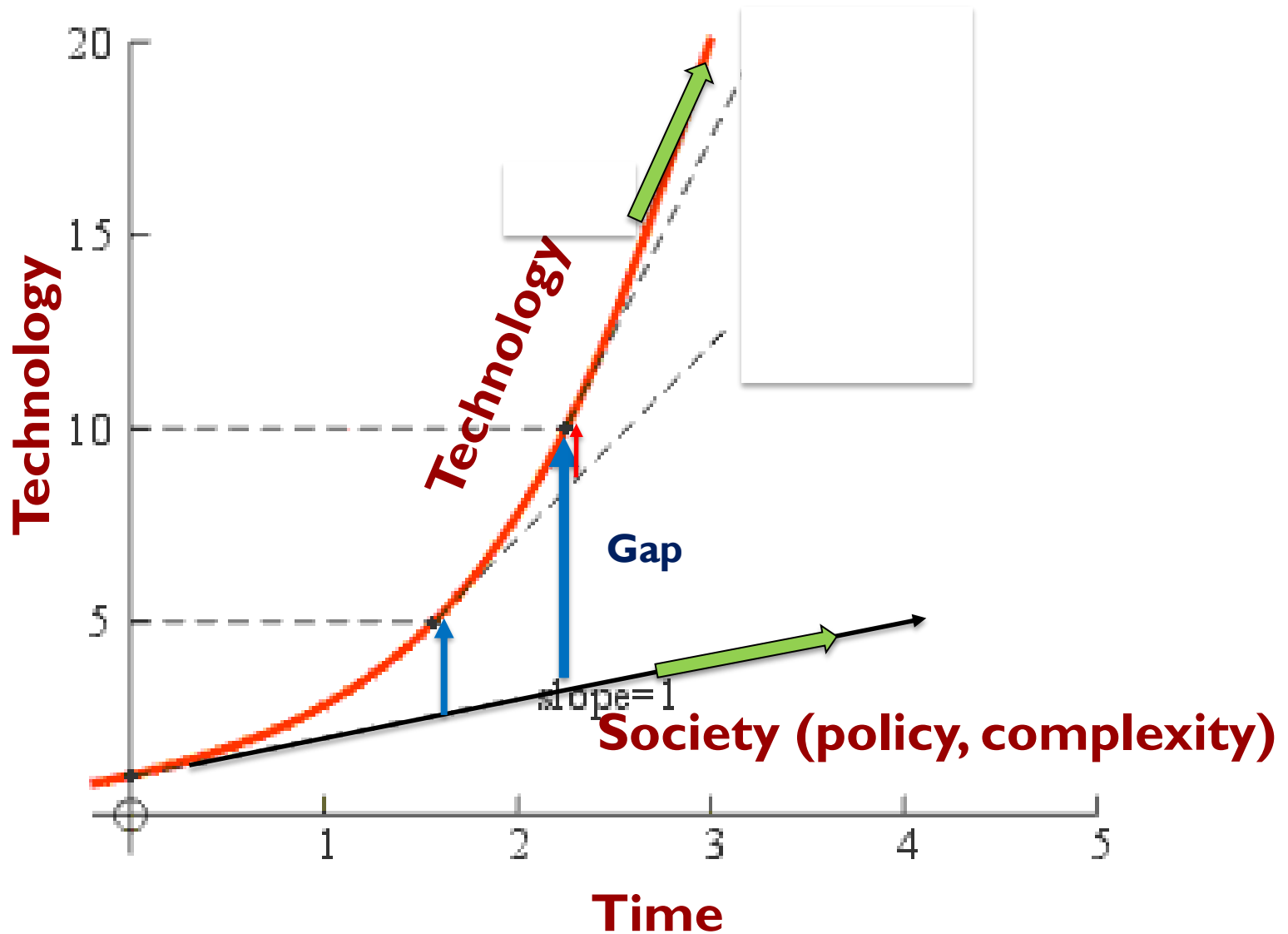




## TECHNOLOGY: EXPLOITING A PHENOMENON FOR *USEFUL PURPOSES\**

- ETHICAL-MORAL
- UNINTENDED CONSEQUENCES
- COMPLEXITY
- POLICY

DECIDE: Center on Decision Making





**A New Vision for Center-Based Engineering  
Research**

**May 2017**

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

A Report of

*The National Academies of*  
**SCIENCES • ENGINEERING • MEDICINE**

THE NATIONAL ACADEMIES PRESS  
*Washington, DC*  
[www.nap.edu](http://www.nap.edu)

**PREPUBLICATION COPY – SUBJECT TO FURTHER EDITORIAL CORRECTION**



IMSC-  
Communication  
Informatics

**USC Annenberg**

School for Communication  
and Journalism

DECIDE  
**USC Price**  
Sol Price School of Public Policy

**USC Dornsife**

Dana and David Dornsife  
College of Letters, Arts and Sciences

**USC Michelson  
Center for  
Convergent  
Bioscience**

**Protein  
Engineering**

**CHARIOT  
Personalized  
Learning**

**USC Rossier**

School of Education

CREATE

*Quantum  
Communications*

Discovery  
Informatics

Irvine  
Center

**USC Roski**

School of Art and Design

**USC Viterbi**

School of Engineering

Keck School of  
Medicine of **USC**

Center for Body  
Computing

HTE@USC

**USC School  
of Architecture**

**USC School  
of Cinematic Arts**

**USC Games**

HBI

**USC Suzanne Dworak-Peck**

School of Social Work

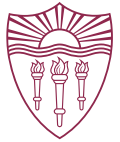
**USC Marshall**

School of Business

**Min Family Engineering  
Social Entrepreneurship  
Challenge**

**AI for Social  
Good**

**Maseeh  
Entrepreneurship Prize  
Competition**



1. BIOSCIENCES

2. QUANTUM COMPUTING AND COMMUNICATIONS

3. IOT

4. CHARIOT

5. MACHINE LEARNING

6. AI FOR SOCIAL GOOD

7. DECIDE

8. ADVANCED MANUFACTURING

Viewed as VC investment- expected to result in large grants, gifts and sustainable growth





**ENGINEERING + BIOLOGY + MEDICINE**

**E2X**

**EUX**

**X2E**



**190,000 GROSS SF; 112,000 NET SF  
IMAGING AND NANOFAB FACILITIES  
UNDER CONSTRUCTION – CERTIFICATE OF OCCUPANCY FALL 2017**

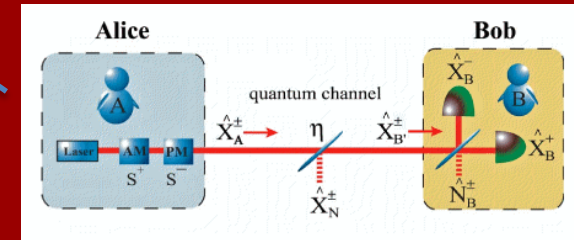


EE, CS and Physics

EUX

## Cybersecurity:

- **Breaking** cryptography  
(made public in Snowden's NSA revelations)
- Provably secure **encryption**  
(guaranteed by the laws of quantum physics)



## Exponentially faster **simulation** of quantum mechanics

➔ first-principles design of novel materials, pharmaceuticals, ...

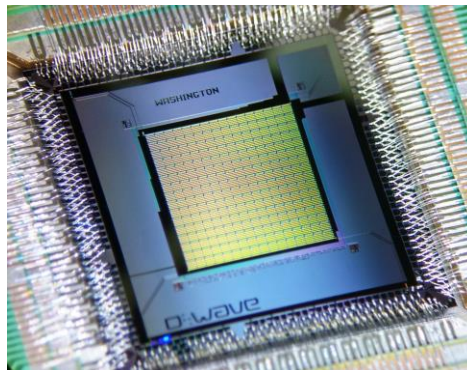
## Quantum speedups in **optimization**

➔ artificial intelligence, machine learning, code debugging, finance, ...



## USC-Lockheed Martin Quantum Computing Center

- \$16M investment by Lockheed Martin in three computers (world's most advanced, largest)
- Since 2011 USC has led the way in quantum Google/NASA, Los Alamos National Lab, others

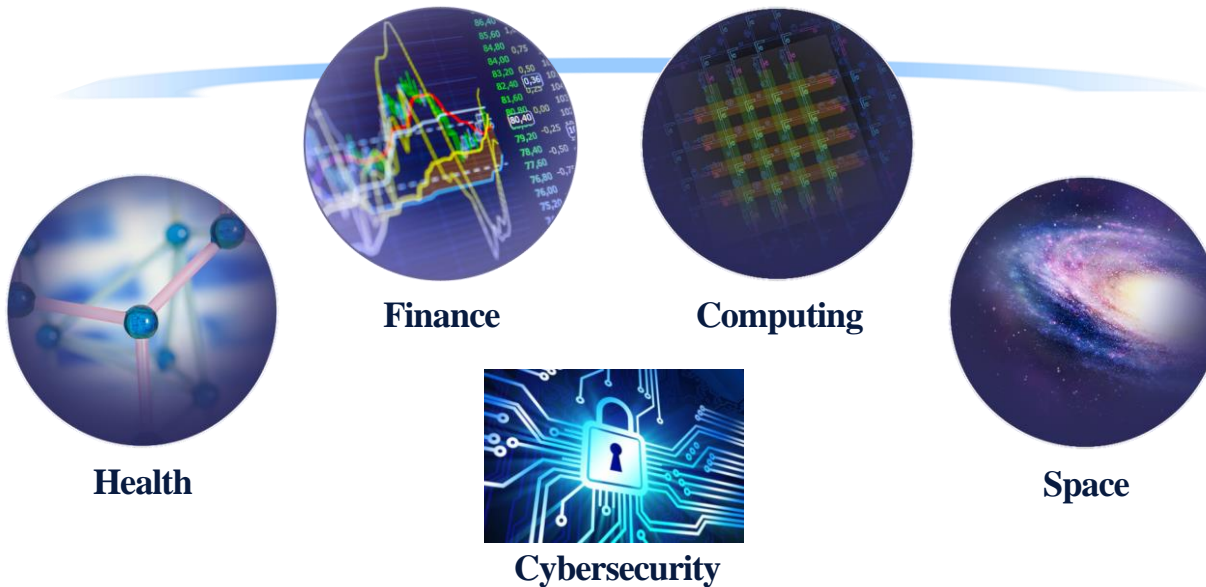


## IARPA Quantum Enhanced Optimization Program

- \$45M / 5yr contract awarded to USC this year
- Will build a new QC using superconducting flux qubits
- Goal: surpass D-Wave to build the world's most advanced quantum optimizer



## Leverage expertise for application-driven QC research



# III. Center for Cyber-Physical Systems and IoT

USC Viterbi

School of Engineering  
Center for Cyber-Physical Systems  
and the Internet of Things



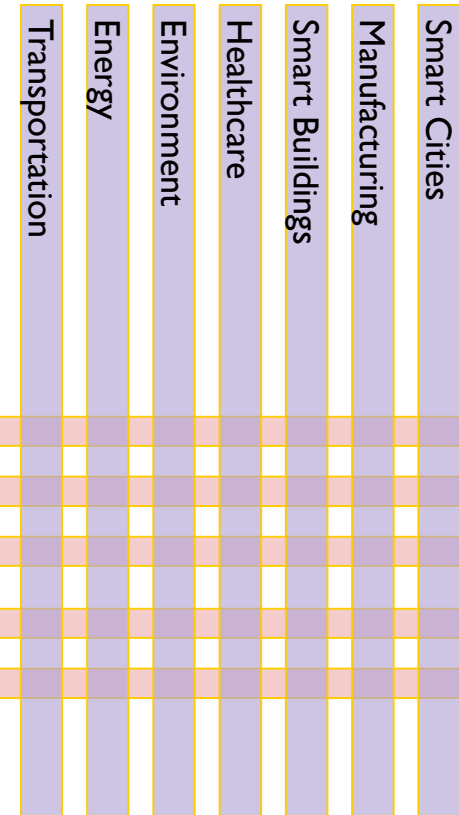
CCI

Thought leadership in the emerging areas of Cyber-Physical Systems and the Internet of Things.

*Horizontal* transformational technologies and *vertical* applications that are undergoing revolutionary changes.

E2X EUX

## APPLICATION DOMAINS



## TECHNOLOGIES AND TOOLS

Security and Privacy

Software Engineering, Interfaces & Visualization

Signal Processing, Data Analytics, Machine Learning, Control

Networking, Middleware, Storage and Cloud Computing

Sensing, Energy-harvesting, and Computational Hardware

Find out more at  
<http://cci.usc.edu>

# IV. Personalized Learning



**CHARIOT**  
CENTER FOR HUMAN APPLIED  
REASONING AND IOT

E2X EUX

A collaboration between USC Rossier School of Education and USC Viterbi School of Engineering to combine cutting edge cognitive science and education research with emerging IoT Technologies to revolutionize **personalized learning**.



Find out more at <http://chariot.usc.edu>

# V. MACHINE LEARNING (MASCLE)

E2X EUX



- › The center conducts world-renowned research work on machine learning
  - › Time series and spatial-temporal data analysis
  - › Network analysis
  - › Image and video analysis
  - › Natural language processing and speech recognition
  
- › **Examples of MASCLE-enabled Applications**
  - › Sustainability – working with LA Mayor’s office on urban heat island analysis
  - › Health care – working with Mayo Clinic, Children’s Hospital Los Angeles, Samsung and Deep Mind on ICU room mortality prediction and diabetes patient monitoring
  - › Social network analysis –social media anomaly detection and fake news detection

# VI. Center for Artificial Intelligence in Society (CAIS)

EUX E2X X2E

- AI research to help solve difficult social problems
- Focus on low-resource communities
- Draw from Social Work & Engineering Grand Challenges, UN Millennium Development Goals



# AI Research Applications

- HIV testing knowledge and behavior among homeless young adults
- Protecting wildlife from poachers
- Preventing suicide among homeless young adults and active-duty military
- Public Safety and Security (e.g., with US Coast Guard, TSA, etc.)



VII.

# USC Decide

Center for Interdisciplinary  
Decisions and Ethics

X2E

The mission of the **Center for Interdisciplinary Decisions and Ethics** (DECIDE) is to enhance the research, education, and practice of decision making on a personal, societal, and public policy level and to increase sensitivity towards ethical considerations in these areas



## Example

Ethical issues concerning the advancement of technology and its effect on society, as well as the decisions that could shape the advancement of technology in ethically sensitive ways.



# VIII. CENTER FOR ADVANCED MANUFACTURING

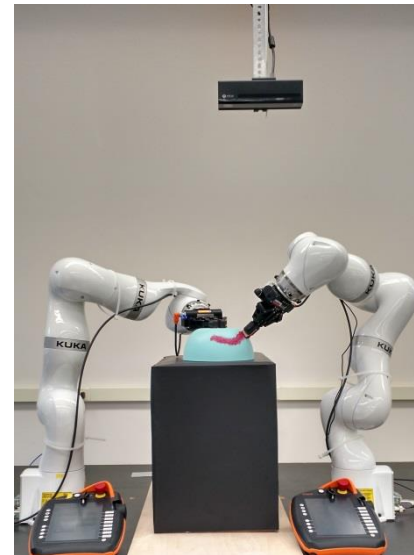
- › Additive Manufacturing
  - » Metals, Composites, Multifunctional, Multiscale, and Microscale
- › Robotics
  - » Human Robot Collaboration, Dexterous Manipulation, Mobile Manipulation, Planning, and Learning
- › Smart Manufacturing
  - » Sensors, Internet of Things, Big Data, Analytics, Machine Learning
- › Digital Manufacturing
  - » Augmented Reality, Virtual Reality, High Fidelity Simulations



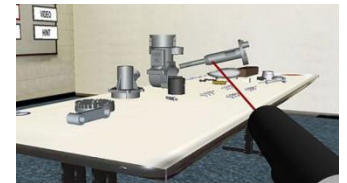
Metal 3D Printer  
EOS M 290 – DMLS



Energy Efficient  
Injection Molding



Kuka Robots



Augmented and  
Virtual Reality

- › Conduct research to enable **advances in manufacturing**
- › Develop **interdisciplinary manufacturing education** programs to enrich learning experiences of USC students
- › Provide **access to the advanced manufacturing** capabilities to the USC community to enable innovation
- › Support **outreach to K-12** community
- › Provide **manufacturing expertise to companies** in the Southern California region



## 1. Talent

students, faculty, staff- and provide environment to flourish.

## PEOPLE

## 2. Value

Continuously adding value to curriculum, programs, infrastructure.

## PROGRAMS

## 3. Thought Leadership- Solving World Challenges

Grand Challenges: energy and sustainability, security and infrastructure, health and medicine, and scientific and technological discovery.

## PAPERS

**4. Impact: Technology Innovation and Entrepreneurship** Silicon Beach, Southern California, the United States, and the World.

## PATENTS



Conceived in 2009 (USC, Duke, Olin):

Adopted by >40 schools nationwide: Supported by the NAE

## 1. Research/creativity

- › Mentored research or project experience related to a Grand Challenge:  
**TECHNICAL COMPETENCE**

## 2. Multidisciplinarity

- › Understanding gained through multidisciplinarity  
**SOFT SKILLS AND COMMUNICATIONS**

**GROWTH MINDSET**

## 3. Entrepreneurship

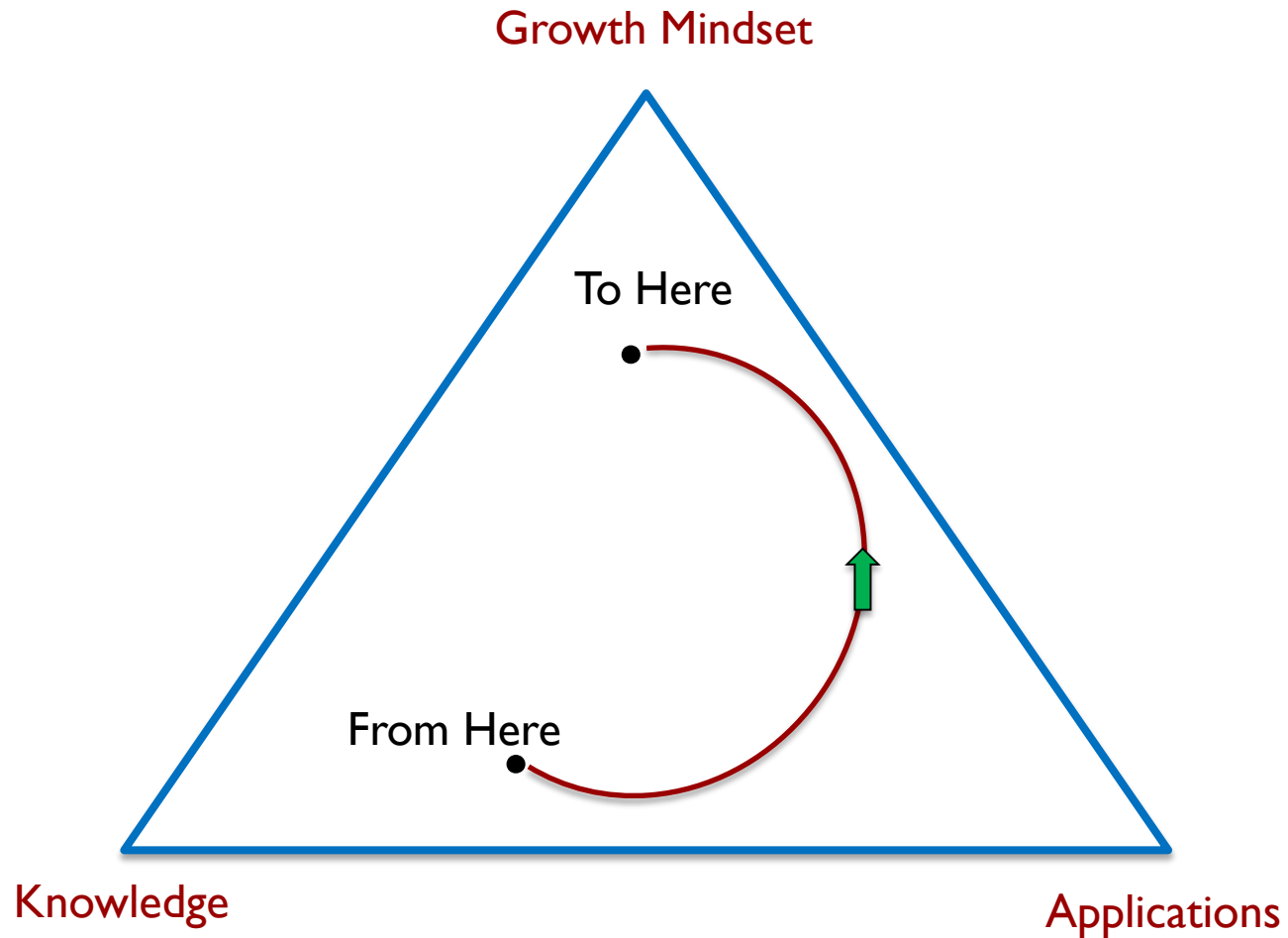
- › Understanding gained through experience that viable business models are necessary
- › **INNOVATION AND ENTREPRENEURSHIP**

## 4. Cultural Competence

- › Understanding gained through global or different cultural experience  
**GLOBAL and LOCAL**

## 5. Social consciousness

- › Addressing societal problems, through service learning, K-12, social entrepreneurship
- › **SERVICE LEARNING; OUTREACH**





## GCSP

**Likely to be *the* engineering curriculum of the future**

Consistent with WEF report on added skills for the 21<sup>st</sup> century:

Creativity, Leadership, Perseverance

Consistent with the *Engineer of 2020*







2009



White House Meeting  
Grand Challenge Scholars Program

2016







Santa Catalina Island



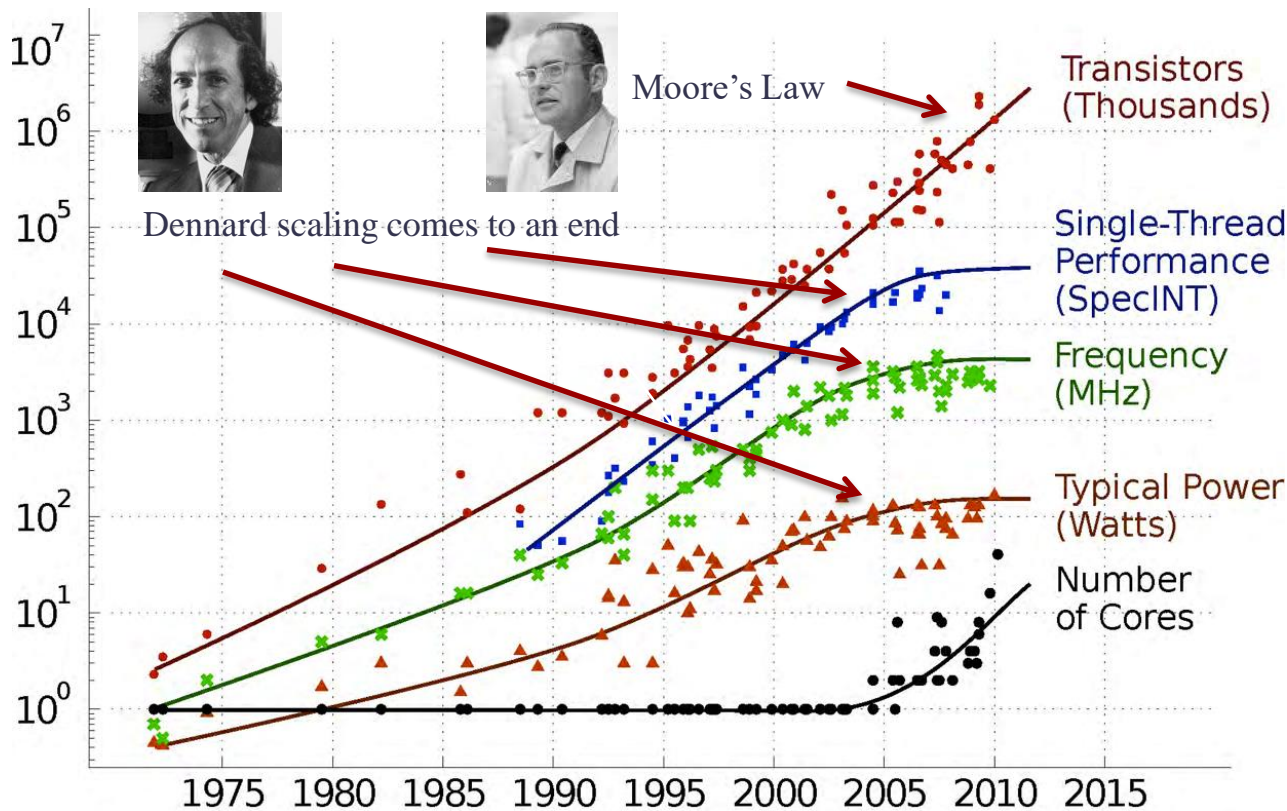


Rhodes Island, The Knight's Castle



# Quantum Computing – Why do we need it?

Inevitability: classical chips hit “the wall of too small”



Data collected by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, C. Batten

- Quantum computers naturally operate at the atomic scale
- They offer a path beyond Dennard scaling
- And so much more...