USC Viterbi
School of Engineering

Engineering in the Era of Convergence

The 4th Industrial Revolution:

Convergence

of physical, chemical, biological, behavioral and social phenomena

CSER 2017 – Yannis C. Yortsos, Dean, USC Viterbi School of Engineering, March 24, 2017

Convergence is an intrinsic part of technology

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*

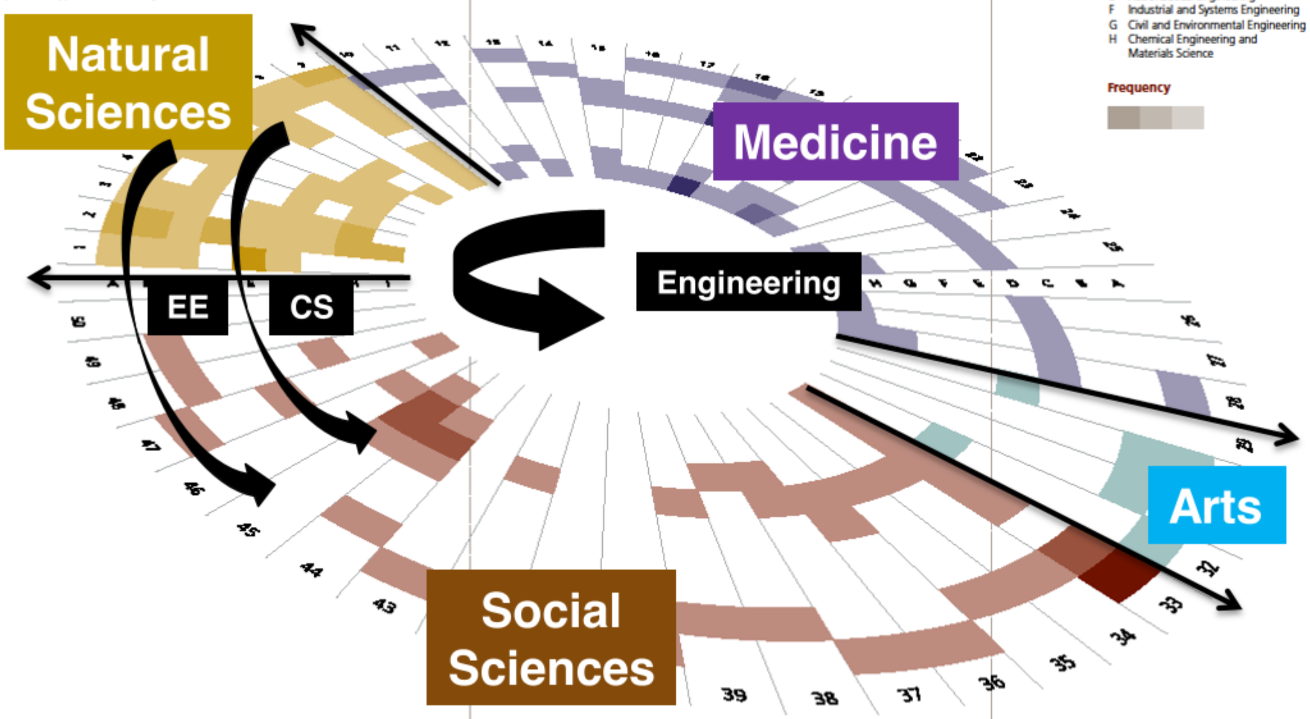
**Including the discovering of new phenomena

Engineering + (2009)

Shaded areas represent 2009 research activity of Viterbi faculty

Engineering+

Engineering+ is simply Engineering + (subject). This radial graph charts the frequency of 50 non-engineering subjects (numbers) through the 8 departments (letters) in the USC Viterbi School of Engineering. The concentric ellipses establish rows and in each row is a letter for each department. The cells generated at the intersections of the numbers and the letters represent the presence of the non-engineering subjects in the research or teaching portfolio of tenured and tenure-track faculty in the departments. The more frequent the appearance of a subject, the darker the cell becomes.



Departments

- A Electrical Engineering
- B Computer Science
- C Aerospace and Mechanical Engineering
- D Biomedical Engineering
- E Astronautical Engineering
- F Industrial and Systems Engineering
- G Civil and Environmental Engineering
- H Chemical Engineering and Materials Science

Frequency

Subjects

SCIENCES
1 Astronomy
2 Biology
3 Chemistry
4 Energy
5 Environment
6 Geology
7 Mathematics
8 Neuroscience
9 Physics

MEDICINE
10 Assistive
11 Biokinesthesiology/Physical Therapy
12 Dermatology
13 Devices
14 Epidemiology
15 Genetics
16 Hearing
17 Cardiology
18 Imaging
19 Informatics
20 Internal/Preventive
21 Neurology
22 Oncology
23 Orthopedics
24 Pediatrics
25 Pharmacology
26 Prosthetics
27 Surgery
28 Vision

ARTS
29 Architecture
30 Cinema
31 Gaming
32 Music

SOCIAL SCIENCES
33 Communication
34 Decision Making
35 Economics
36 Education
37 Emergencies
38 Geography
39 Government
40 Internet
41 Journalism
42 Law
43 Linguistics
44 Management
45 Manufacturing
46 Policy
47 Psychology
48 Safety/Security
49 Sociology
50 Urban Studies

Convergence

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)

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)

E and X can be vectors

Convergence Paths

X2E

X EMPOWERS E

We will call it X-mimetic

Biomimetic: Nature's optimization through evolution

Perhaps other

Convergence Paths

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

(Exponential Technologies)

Emotions, Judgement, Character, Ethics, Morals, …

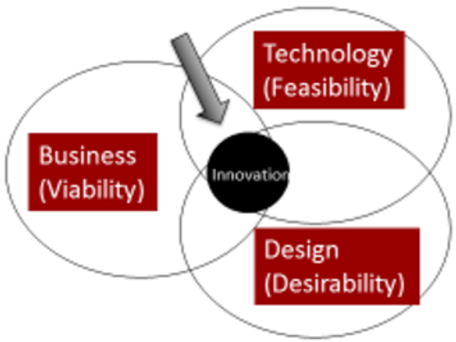
What if X is human or society-centric?
e.g. In Complex Systems

- E2X: Enables social or behavioral phenomena
  Social Media; AI for Social Good
- X2E: Ethical decision making in autonomy
  Drones, driverless cars
- EUX: Augmented Intelligence
  HMI (human-machine interaction)
  HBI (human-building interaction)

(Also, any businesses, organizations, systems, innovation)

TWO EXAMPLES

INNOVATION IS INTRINSICALLY CONVERGENCE



Useful Purposes

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

- ETHICAL-MORAL
- *UNINTENDED CONSEQUENCES*
- COMPLEXITY
- POLICY

DECIDE: Center on Decision Making

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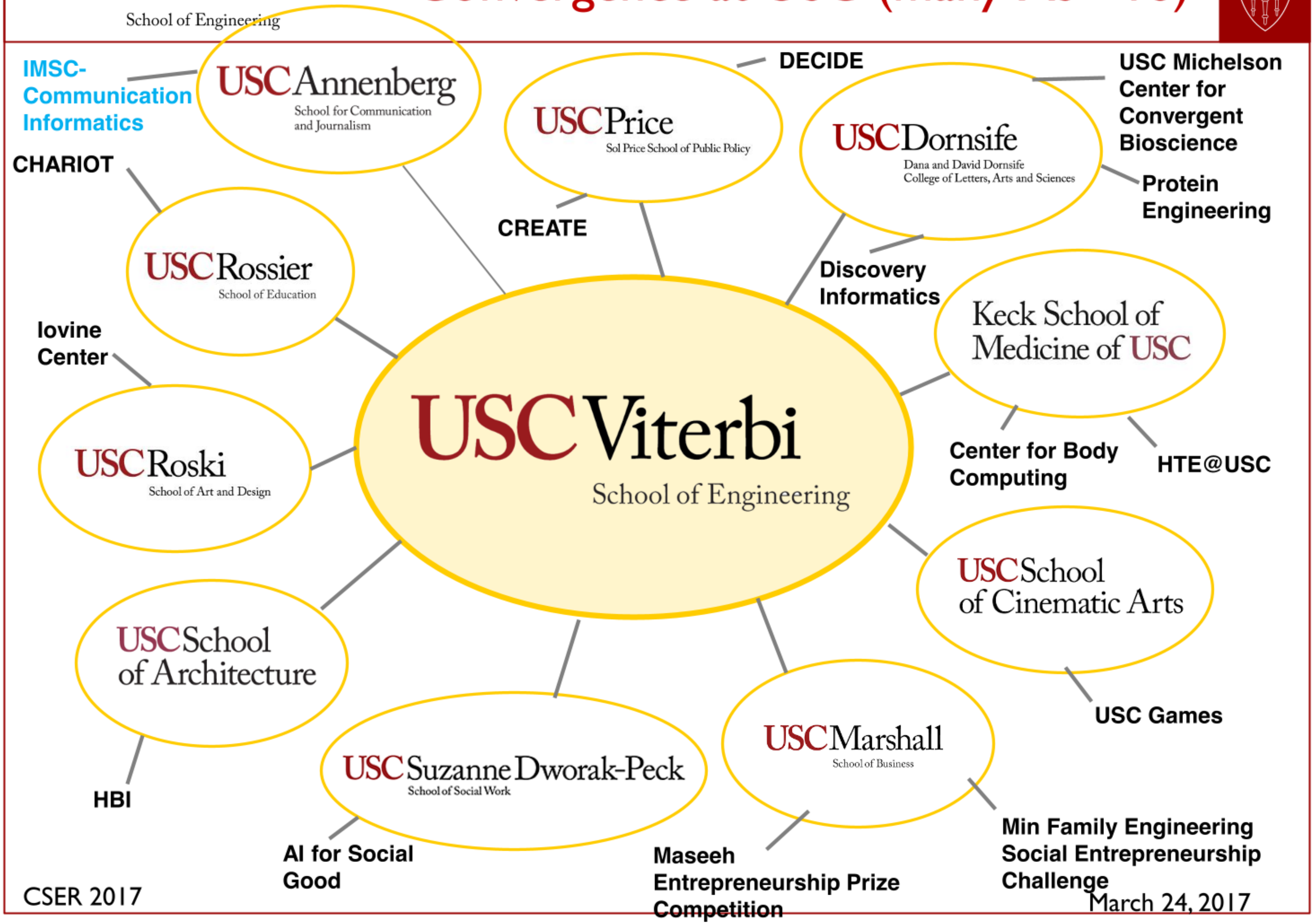
Convergence at USC (many Xs =18)



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SEEDING CONVERGENCE CENTERS:

1. BIOSCIENCES
2. IOT
3. CENTER FOR ADVANCED MANUFACTURING
4. MACHINE LEARNING
5. AI FOR SOCIAL GOOD
6. DECIDE

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

Currently

Econophysics: Use of statistical physics to explain economics.

Agent-Based models: Discrete entities interact through rule-based interactions.

1. *Each entity assigned a state property, updated through rules based on neighboring states.*

2. *Sometimes expressed through conservation laws and flux-flow relationships.*

Helbing, Quantitative Sociodynamics, Springer 2010.

Modeling Social Phenomena: The Case for a Chemical Description

At the fundamental unit (single-human) level, all social phenomena fundamentally involve *(bio) chemical reactions*. Behavioral responses often mimick the same.

Interested in the aggregate (interaction of multiple entities)=> Natural to seek *chemical kinetics analogues*.

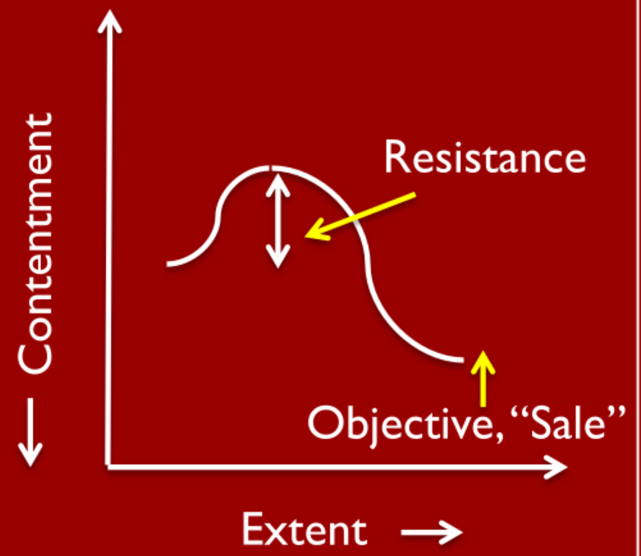
Econochemistry: James F. Duncan, "The Chemistry of Social Interactions", Tech. Forecasting and Social Change, **60**, 167-198 (1999). Cited once since published!

The (Chemical) Kinetics of Social Phenomena

Postulate:

All social interactions where there is a "chemical transformation" across many elements ("humans" as molecules): can be modeled as a chemical reaction

$$A + B \rightarrow C$$



- Culture $A^* + B \rightarrow A^* + B^*$

- The process of sales (or reaching objectives) $A^* + B \rightarrow A + B^*$

- Transformative "experiences"

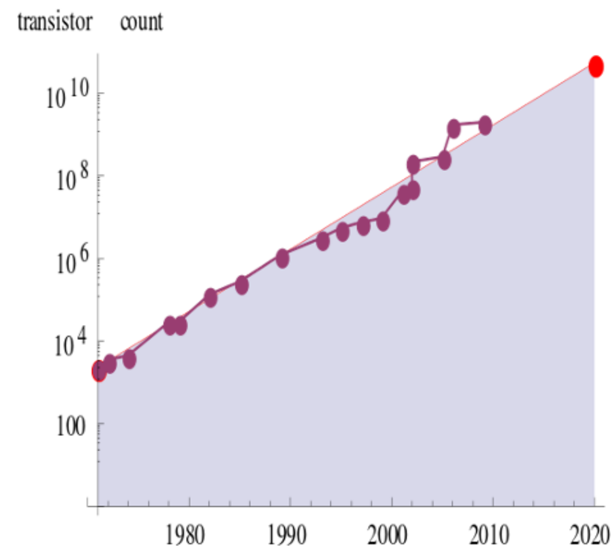
The (Chemical) Kinetics of Social Phenomena

Requires

-Definition of "species", "reactants" and "products"- e.g. demographic, ethnic, geographic, or basis of "contentment", or of knowledge
-Random walks (e.g. web surfing?) and collisions
-Activation "energy" barrier and change of "energy" state
-Definition of an intermediate "complex" and the probability of its formation (political, legislative processes?)

May help model, understand and possibly control the phenomenon

Chemical Kinetics for the Evolution of Technology



LINEAR KINETICS: $A \to A$

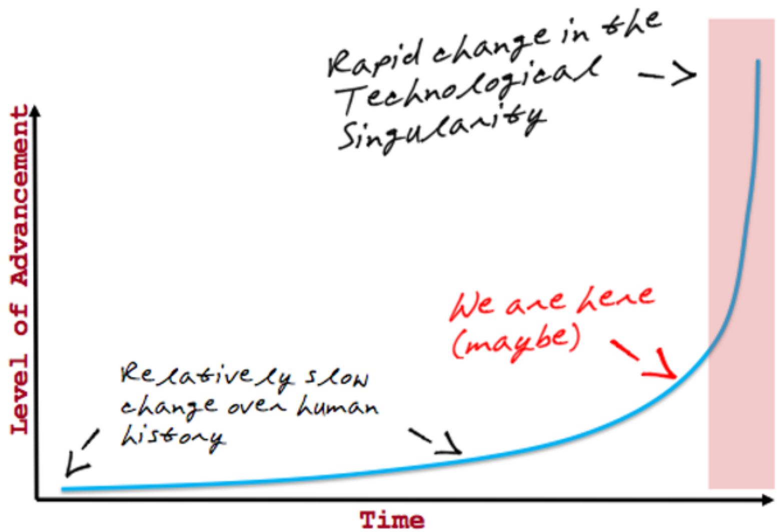
$$\frac{\Delta A}{\Delta t} \approx \lambda A \Rightarrow A \approx A_0 \exp(\lambda t)$$

EXPONENTIAL INCREASE: MOORE'S LAW!

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

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

SINGULARITY AT t^*!
KURZWEIL'S CONJECTURE?

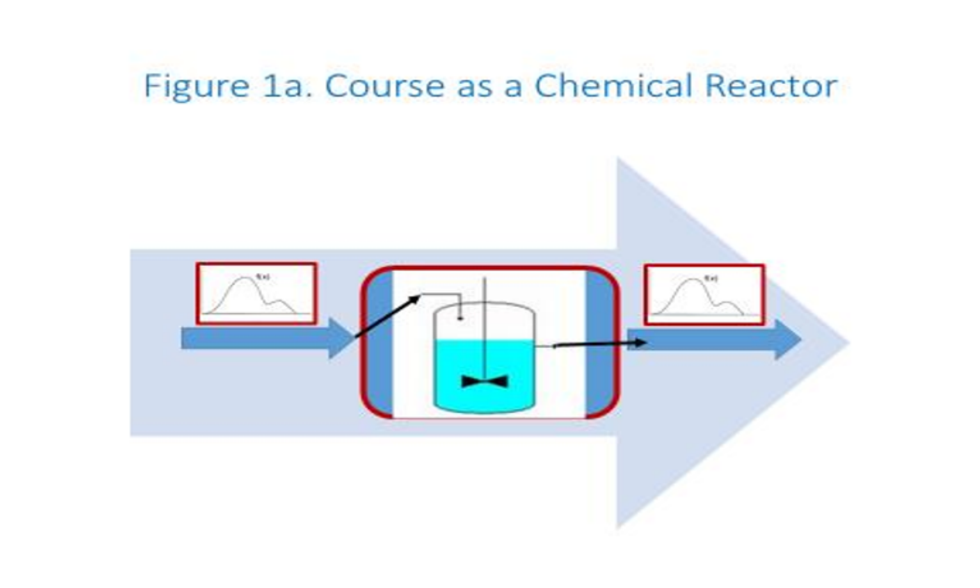


Education as a Chemical Reaction Process

<u>Education</u>: the process of facilitating learning; also augments an individual's state of knowledge or skillset: *A "chemical reaction"*

$$A \longrightarrow A^* \qquad (1)$$

<u>Individual course</u>: education in a specified time interval (typically quarter) and a prescribed sequence: A *"chemical reactor"* where (1) occurs



Education as a Chemical Reaction Process

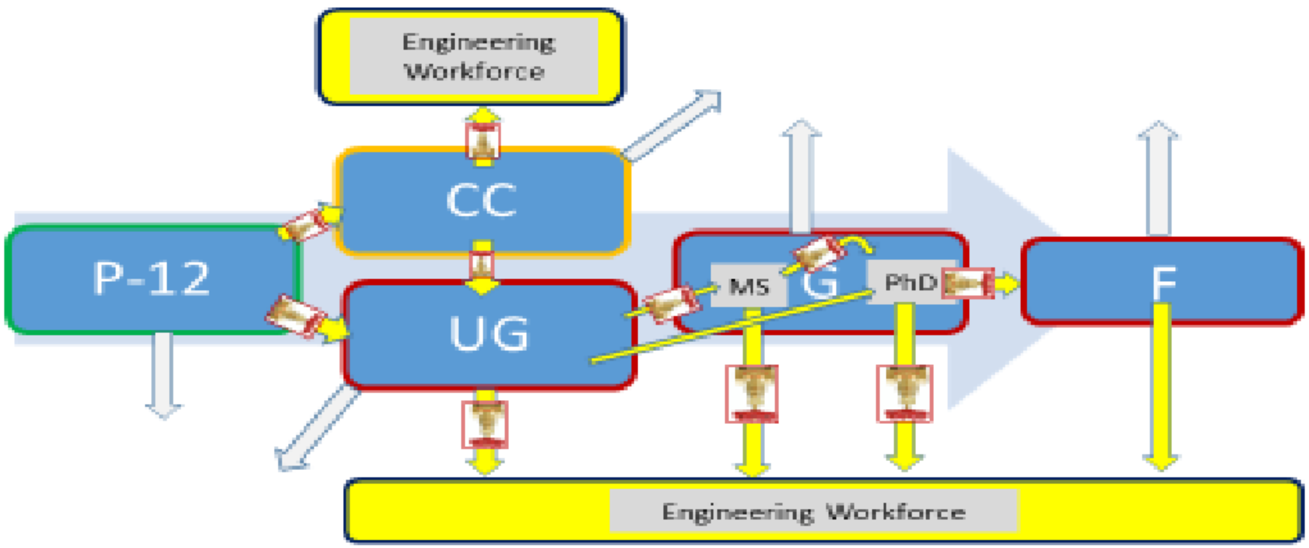
Curriculum: A *"flow and reaction" process*, where a new cohort enters each year, with an overall residence time of 4 years, for a typical curriculum.

Figure 1b. Curriculum as a Sequence of Chemical Reactors

Education as a Chemical Reaction Process

Engineering Education "flow diagram": Each part consists of individual "control volumes" (within each of which is a sequence of "chemical reactors").

Figure 2. Engineering Education as a Flow Process



Implications for Diversity and Inclusion

Figure 3. Parity:
Key measures of input and output are demographically invariant

- Process efficiency in each control volume necessarily means parity.

- Namely, demographics of output flow rates (e.g. undergraduate retention or graduation rates) must be statistically the same as those of the input.

- Entities owning control volumes and flow rates (admission valves), must own and be accountable for reaction efficiencies through them (i.e. parity).

- Best practices ("control strategies") needed to meet such objectives.

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EDUCATION AS A CHEMICAL REACTION PROCESS

- Enhance D+I by establishing parity on input and output.
- Parity is process efficiency, to which an institution ought to aspire.
- Best practices should be developed to meet the parity objective.
- Wide adoption of the parity objective will have a non-trivial impact on increasing engineering D+I.
- If every engineering institution commits to this in each of the control volumes it owns, will automatically strengthen output flows, thus increase downstream flows.

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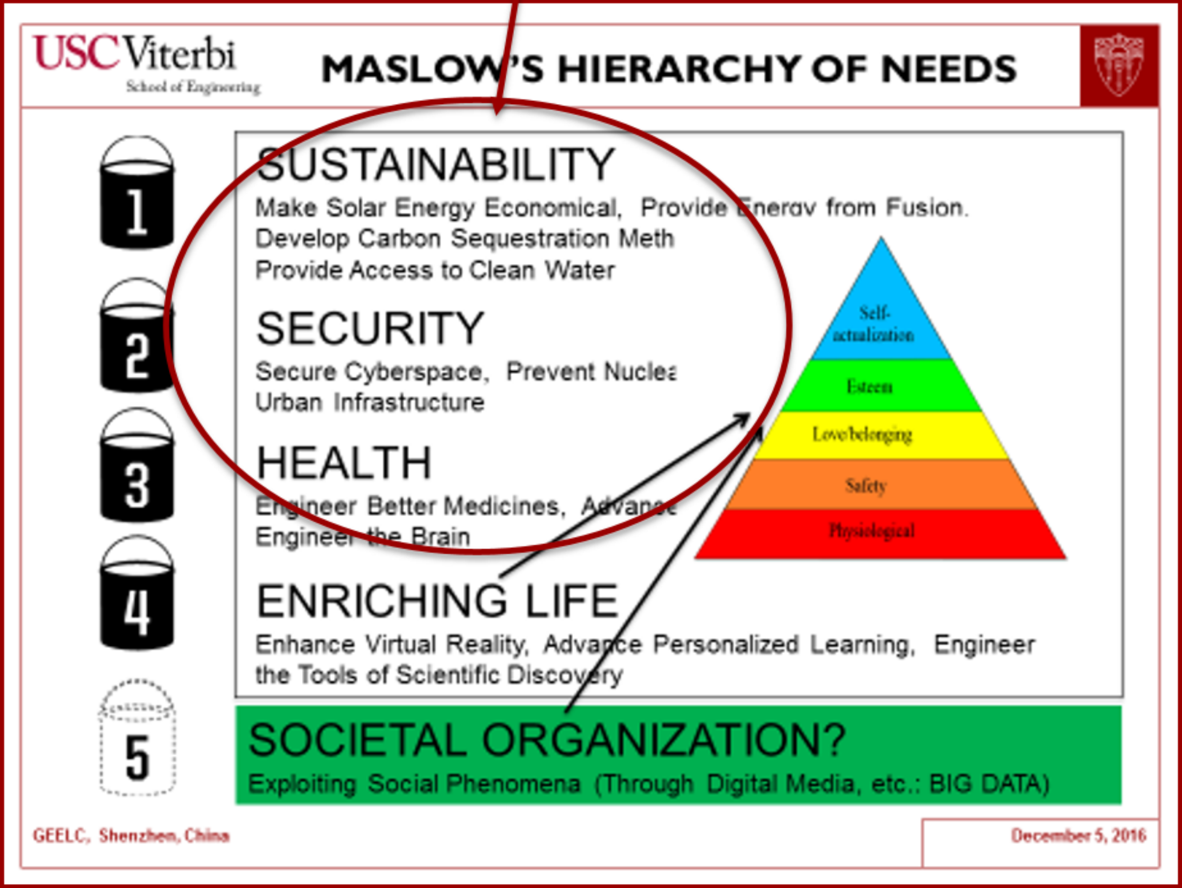
Convergence *of physical, chemical, biological, behavioral and social* phenomena: Address the fundamental needs in Maslow's hierarchy



In order to be able to further enrich life