Engineering 2.0: Rekindling Technological Innovation and Advanced Manufacturing

Sridhar Kota

Herrick Professor of Engineering
The University of Michigan, Ann Arbor

Executive Director, MForesight : Alliance for Manufacturing Foresight

Former Assistant Director for Advanced Manufacturing (2009-2012),
White House Office of Science and Technology Policy

International Council on Systems Engineering (INCOSE) – Cleveland Chapter
November 13, 2017

Engineering

Concept → **ENGINEERING** → Successful Product

Engineering Science

- Analysis
- Modeling & Simulation
- Optimization
- Sensitivity analysis
- Process simulation/opt

Engineering Design/ Synthesis

- Systems design
- Systems Engineering

Performance
(incl. lightweight, compact etc.)
Reliable
Cost-effective
Safe
Easy to manufacture
Easy to maintain

Engineering science (analysis) is an intermediate step in engineering systems.

Systems Engineering

Definition of Systems Engineering from INCOSE:

interdisciplinary
design synthesis
modeling, integration, validation, and verification, redesign

a structured development process that proceeds from concept to production to operation.

Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.

This is the definition of Engineering

Are we teaching this in engineering schools?

Engineering is the Centerpiece of Technological Innovation

According to National Academies,

"Innovation commonly consists of being

first to acquire new knowledge through leading edge research,

first to apply that knowledge to create sought-after products and services, often through world-class engineering; and being

first to introduce those products and services into the marketplace through extraordinary entrepreneurship."

Innovation is really about transforming ideas and emerging technologies into practical solutions at scale to meet societal needs

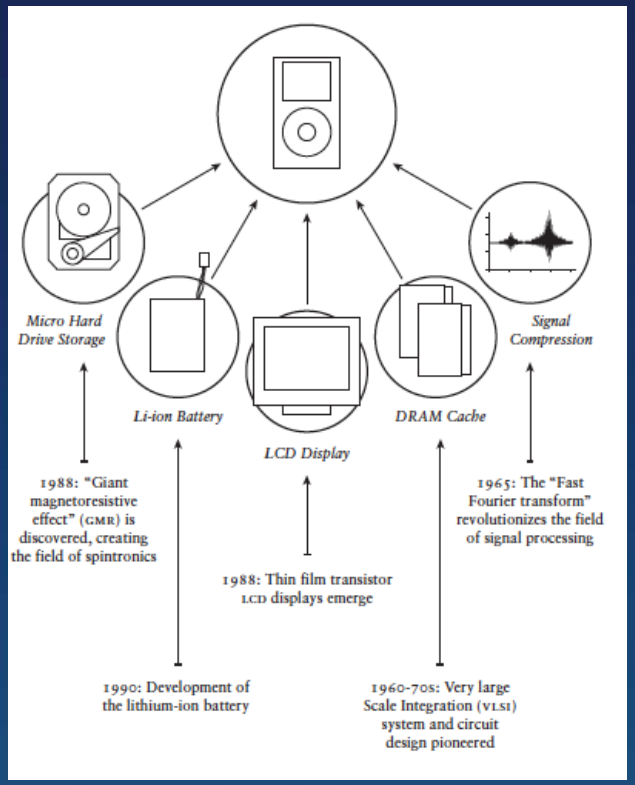
Creating Knowledge but Not Wealth

Scientific Discoveries → Engineering Inventions →Innovation → Manufacturing,..

Federal S&T investment
~ $140 billion annually

Mfg. deficit ~ $600 billion
Adv. Tech. Products deficit ~ $100 billion

The Innovation Gap



Research funded by DoD, NSF, NISH, DOE and NIST contributed to the breakthrough technologies that enabled mobile devices

The U.S is steadily falling behind in capitalizing on its own discoveries & inventions: robots, displays, cell phones, Li-ion batteries etc.

Being the world's best in science is still vital to our success but is no longer sufficient to compete in the global economy

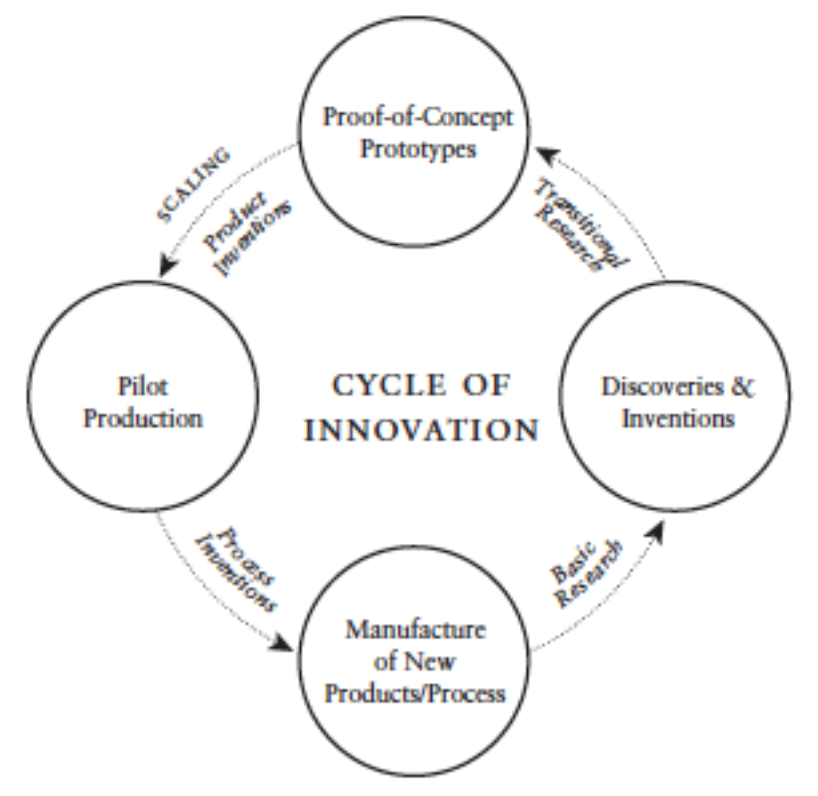
Erosion of Industrial Commons

- Offshoring manufacturing: “Invent here, manufacture there” – 6 million manufacturing jobs lost

- Degradation of “industrial commons” - the broad and deep ecosystem of skilled trades, engineers, production experience, and productive capacity needed to innovate both products and processes.

- Offshoring R&D- “innovate there, manufacture there”

- Dearth of financing for “hardware startups” - hardware start-ups emerging from U.S. research labs are turning to foreign investors and often moving scale up production overseas



Offshoring Innovation

"Chinese firms pour money into U.S. R&D in shift to innovation"

"over the last five years (2011 - 2016), the three Chinese internet giants have completed over 50 investments into US-based startups"

In 2015, China-based firms invested $10 billion in U.S. tech startups - about one-fifth of the total money raised by U.S. tech startups that year. Robotics, drones, virtual reality, autonomous cars, artificial intelligence, predictive analytics

In 2012 General Motors opened its new GM China Advanced Technical Center in Shanghai

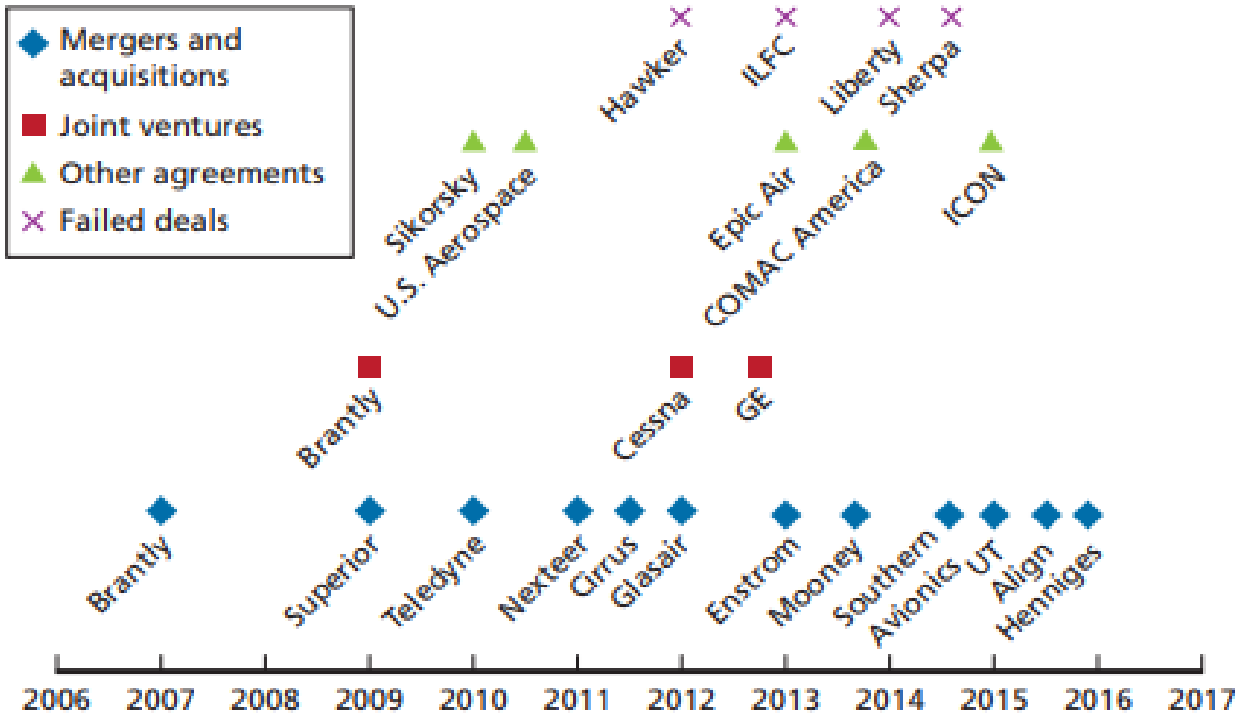
In 2010, Boeing and Tsinghua University launched a joint research center in Beijing

Pharma/Biotech Companies are setting up R&D in China & India. Example Pfizer invests $350 million biotech center in China in 2016

Chinese biotechnology start-ups partner with the world's biggest drug companies to develop new medicines to treat everything from cancer to hepatitis

In 2010 GE Healthcare announced $500M, 6 R&D centers in China

Figure S.1
Timeline of Chinese Investments in U.S. Aviation



SOURCE: Compiled by authors from multiple sources.

RAND RR1755-S.1

https://www.uscc.gov/sites/default/files/Research/RAND_Chinese%20Investment%20in%20US%20Aviation_FINAL.pdf

Engineering & Technology Innovation

- Investments in scientific research produce indispensable knowledge, but it is by applying that knowledge through rigorous engineering and practical development that people and nations produce wealth, thereby achieving economic strength, and national security.

- Between 2001 and 2013 U.S. trade in Advanced Technology Products grew from surplus to nearly $90 billion deficit.

- A core problem lies in America's failure to maintain one of its historical core strengths: engineering

This is NOT Rocket Science

It is Rocket Engineering

Science is not engineering

Dissect frogs in HS – why not power tools

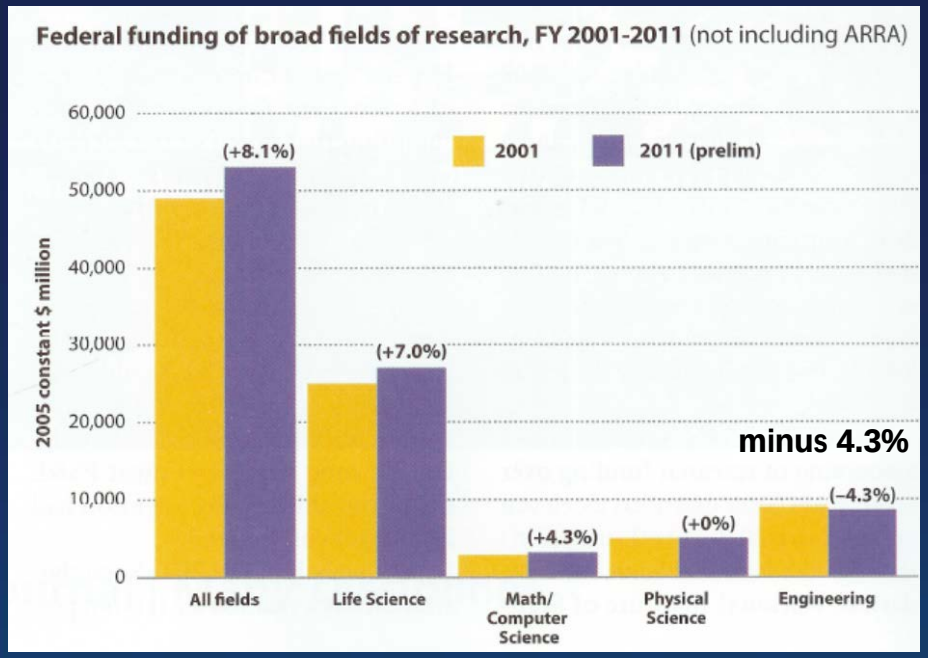
FIRST Robotics – it is not about robots

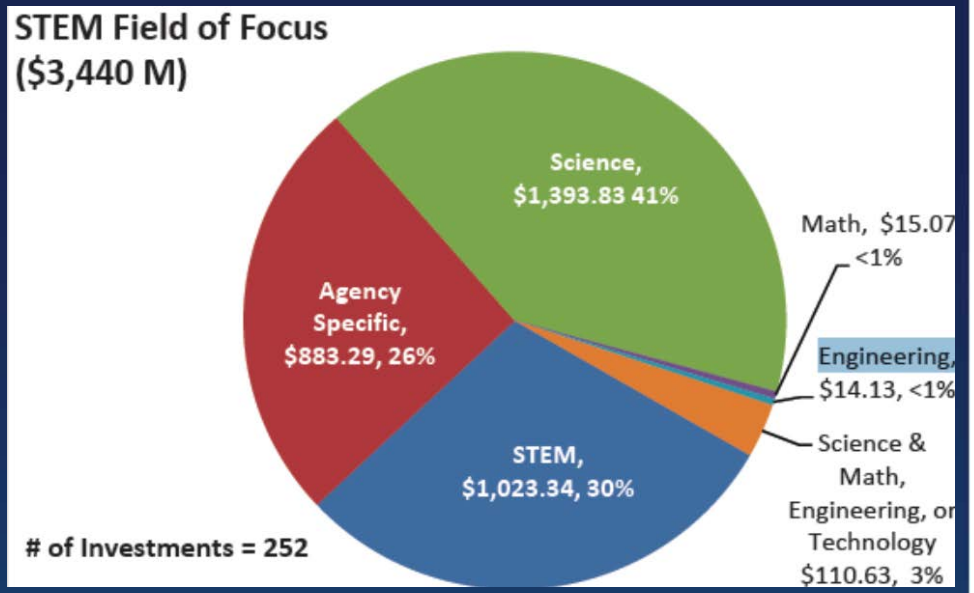
Teach engineering in the middle/high schools

Promote engineering as a creative discipline

Generalization of science to include engineering has had real consequences in our investments and outcomes in research, education and innovation

Investments in Engineering Research and Education



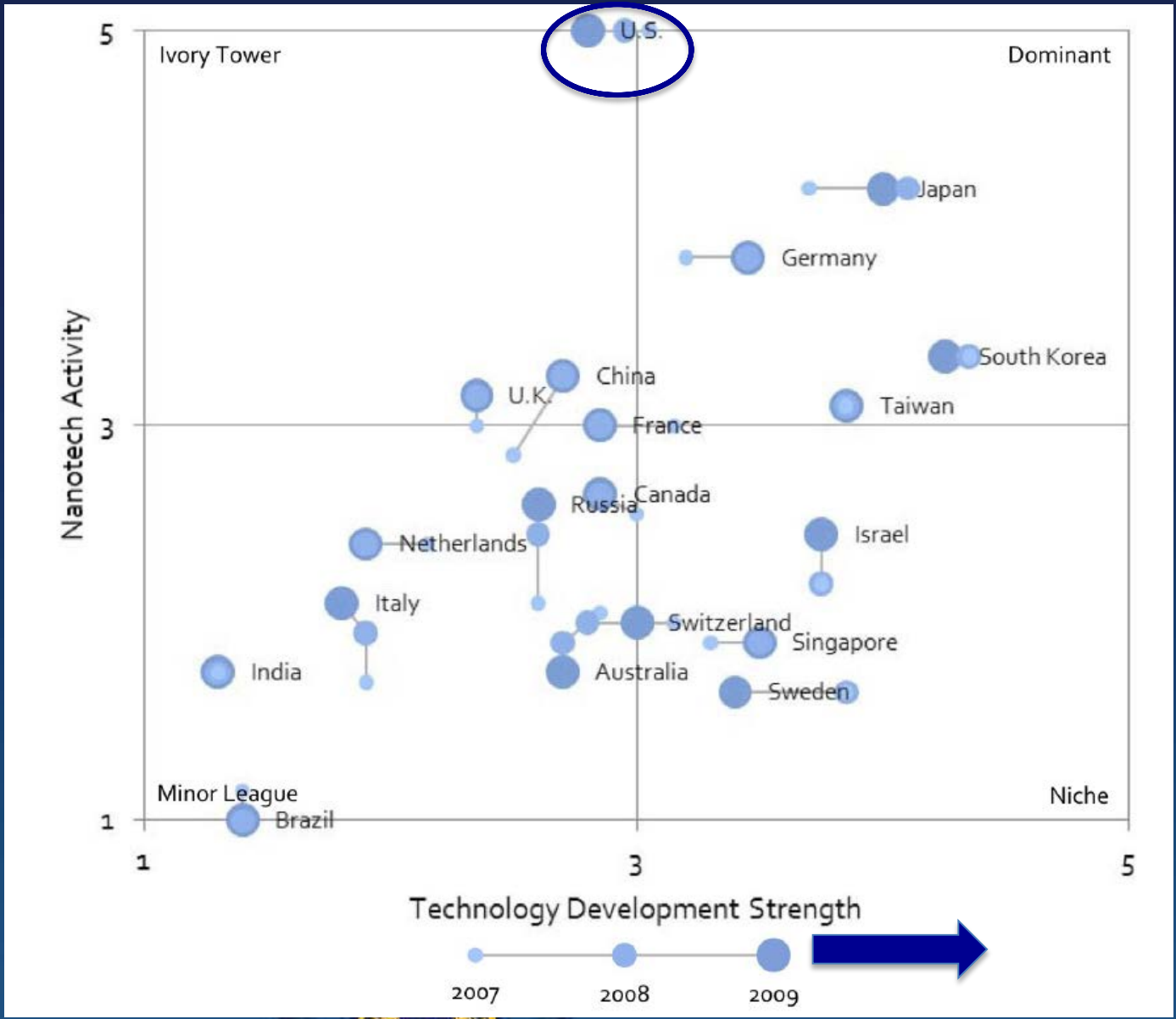


Source; NSF Science and Engineering Indices 2011

Source: Stephen Merrill, " A perpetual Imbalance- Federal Funding of Physical Sciences and Engineering Research," Issues in Science and Technology, Winter 2013

Research Outcomes

Source: "Ranking the Nations on Nanotech"-
Lux Research Report, Aug 2010



Role of Government: Innovation Policy

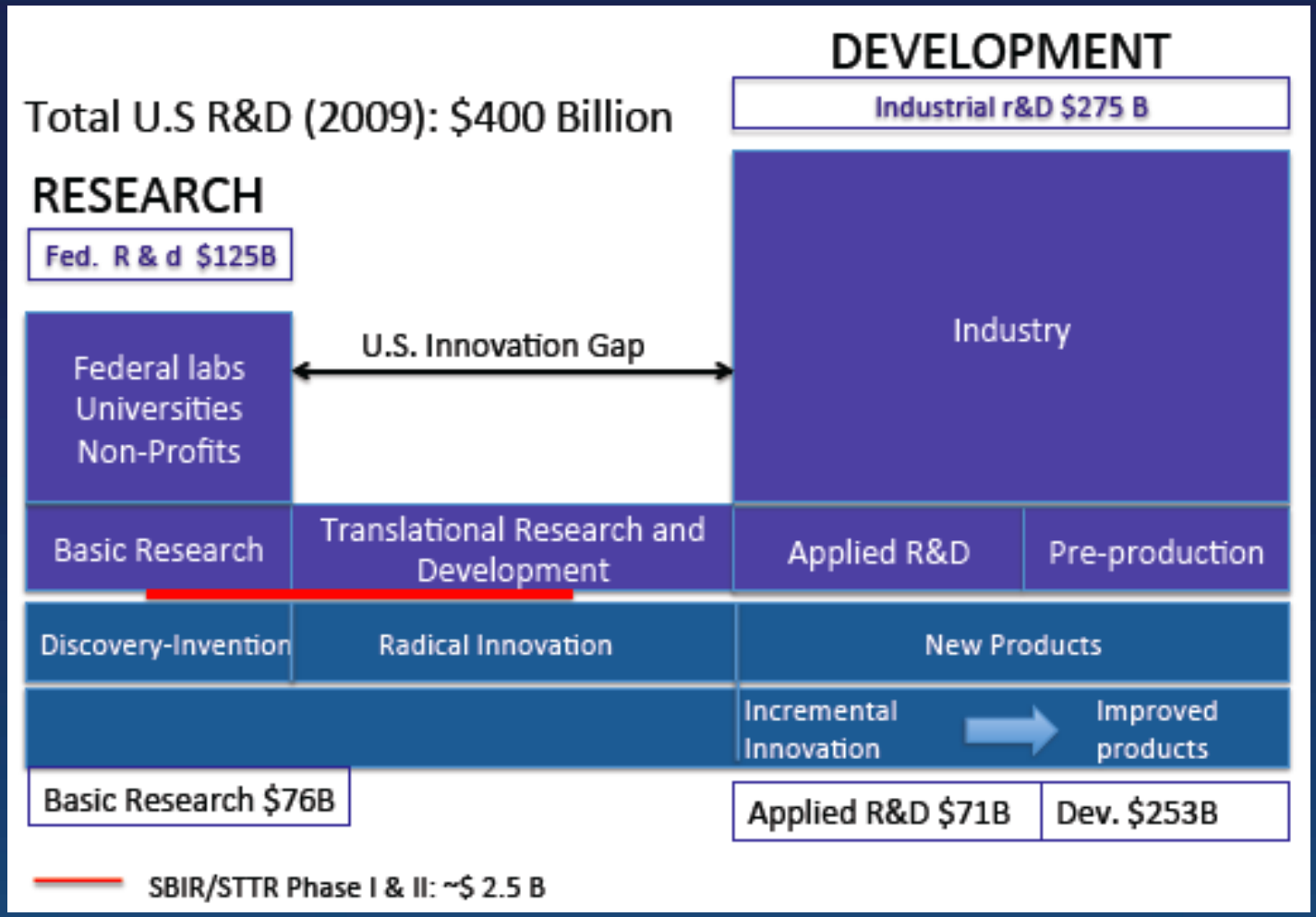
- Corporate R&D focus is mostly short term
  - The "Bell labs" of yesteryear have disappeared; they used to do both basic research (science) & translational research (engineering)

- Private sector is less inclined to invest in nascent technologies
  - Technical and market risks
  - Market failures, spill-over effects – no one company or industry can capture the full benefits of its investment in emerging technologies

- Role of Government: Innovation Policy
  - Historically, the U.S Government has made long-term investments in R&D and accelerated innovation through early adoption

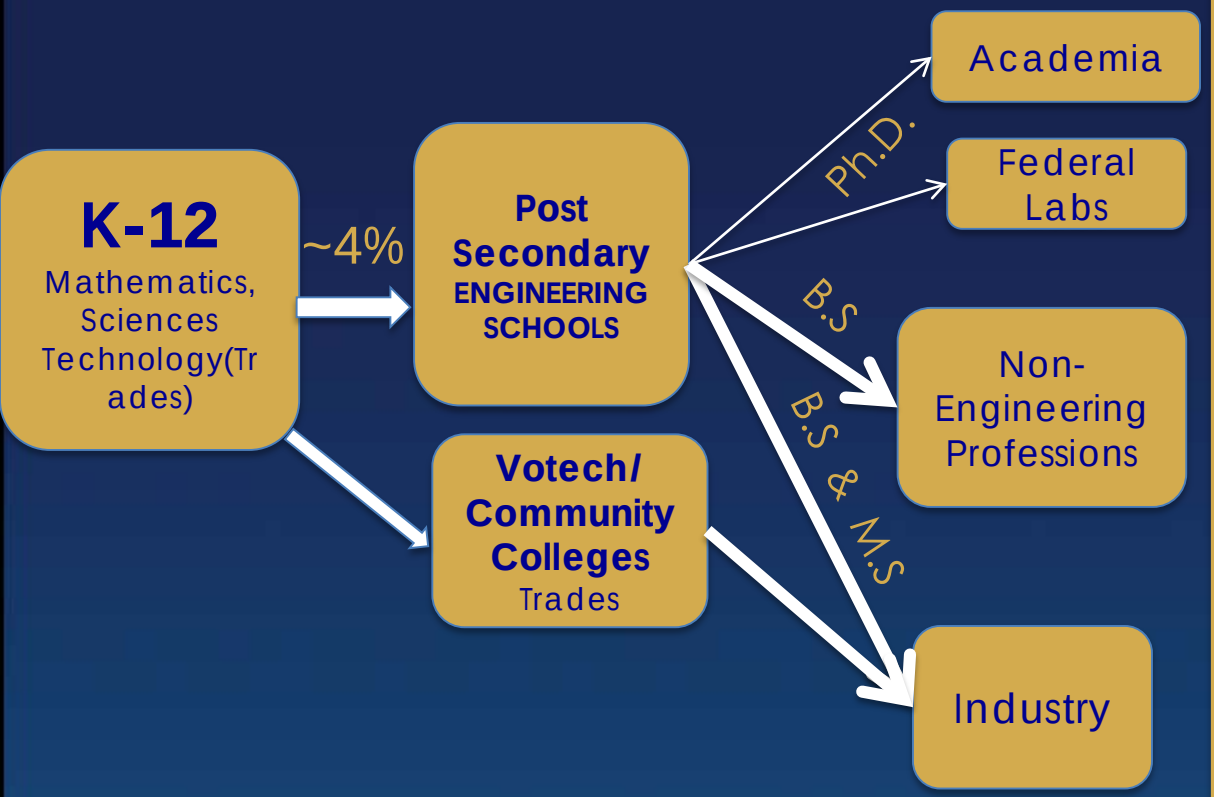



Invest in precompetitive translational (engineering) R&D to create industrial commons needed to mature emerging technologies and their manufacturing readiness and anchor manufacturing here in the U.S



Since the announcement of the first Manufacturing Innovation Institute in March 2012, nearly $2 billion invested to-date by the public and private sources to establish 14 National Network of Manufacturing Innovation Institutes

Outcomes: The Missing E in STEM



Gender gap?

Women in Engineering
(% degrees awarded- overall)

B.S. 19%; Ph.D. 22%

Environ. Eng. :	45%, 40%
Biomed. Eng. :	40%, 36%

Engineering school's mission to produce engineering innovators

50% of Olin's graduates are women!!

Exposure to real-world engineering will inspire our youth to attend a four-year engineering college or pursue vocational training, without feeling like a second-class intellect

Bring Maker Faire, FIRST Robotics type of education and experience into mainstream K-12 curriculum.

Role of Universities & Industry

Research:

- Put "&" back in R&D

Education:

- Rebrand & rekindle engineering as a creative discipline for inventors, innovators and entrepreneurs.
- Industry should revamp internships and apprenticeship programs to create educated and skilled workforce at all levels

Outreach:

- Organize summer innovation camps for middle & high school students
- Inspire young and the old about "rocket engineering"

- Role of INCOSE, MForesight… Discussion

MForesight