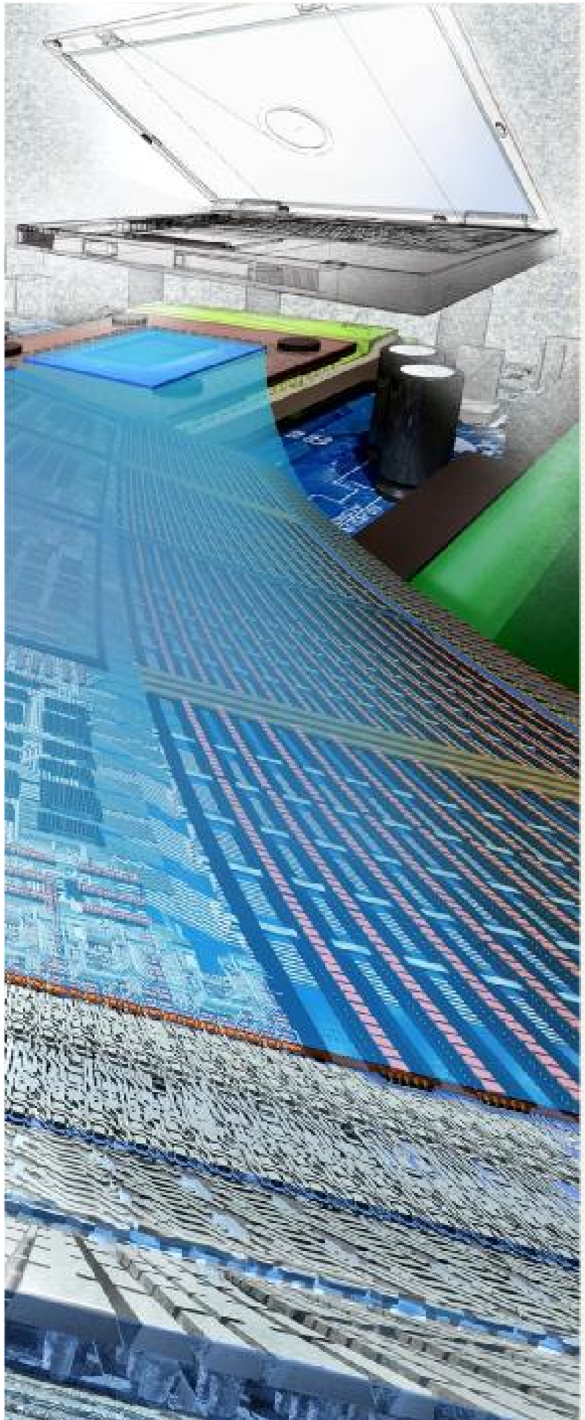


Image Credit: Exploratorium.

Unleashing the Discovery and Innovation Ecosystem

Farnam Jahanian
Carnegie Mellon University

Symposium on Continuing Innovation in Information Technology
The National Academies
Washington, DC

March 5, 2015

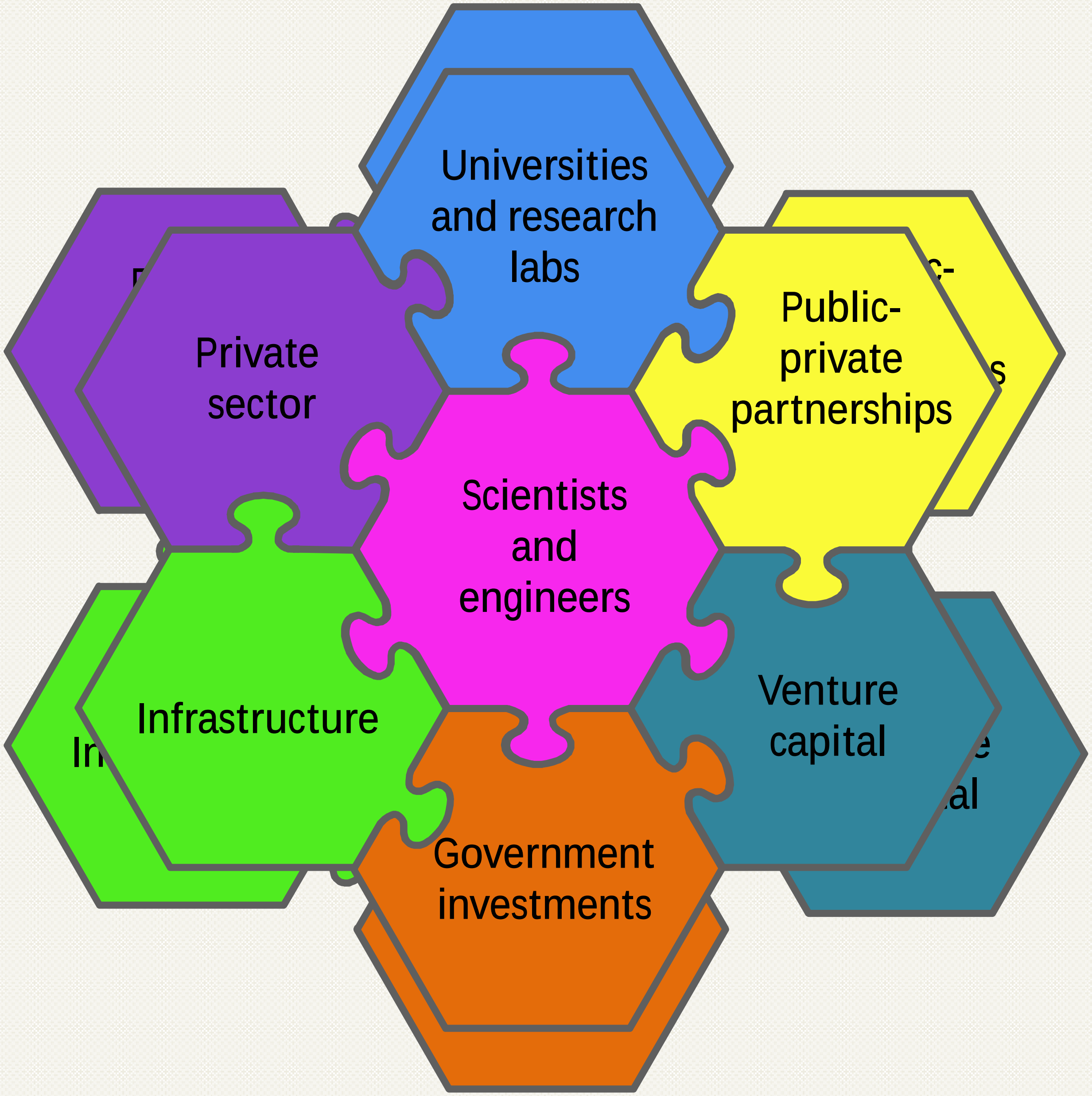
Innovation

"Innovation distinguishes between a leader and a follower" -Steve Jobs, 2005

Image Credit: Mindwerx International

"The guy who invented the first wheel was an idiot. The guy who invented the other three, he was a genius." -Sid Caesar

Discovery and Innovation Ecosystem



Pervasive Impact

- Advances in computing, communication and information technologies:
  - Underpin our **economic prosperity** and **national security**;
  - Serve as a key driver of economic **competitiveness** and **sustainable growth** in an increasingly global market;
  - Accelerate the **pace of discovery and innovation** in nearly all other fields of inquiry;
  - Are crucial to achieving our major **national and societal priorities**.

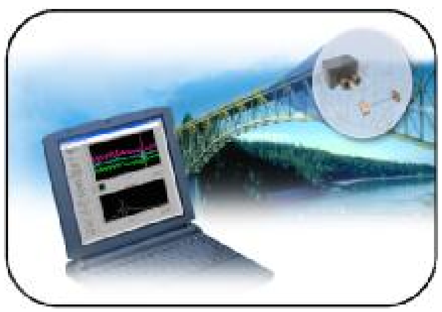
Pressing Societal Challenges Require Interdisciplinary Approaches

Health & Wellbeing

Understanding the Brain

Emergency Response and Resiliency

Secure Cyberspace & National Defense



Manufacturing, Robotics and Smart Systems

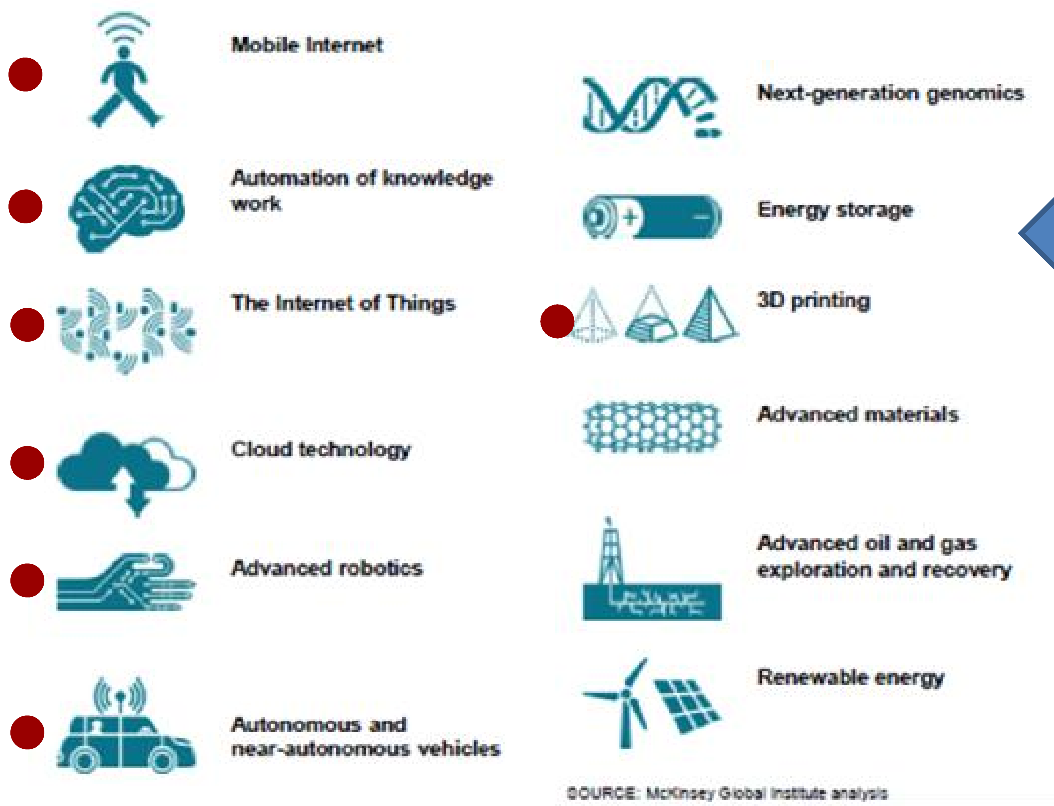
Environment and Sustainability

Transportation & Energy

Education & Learning Science

The Future ...

Top twelve economically disruptive technologies (by 2025)



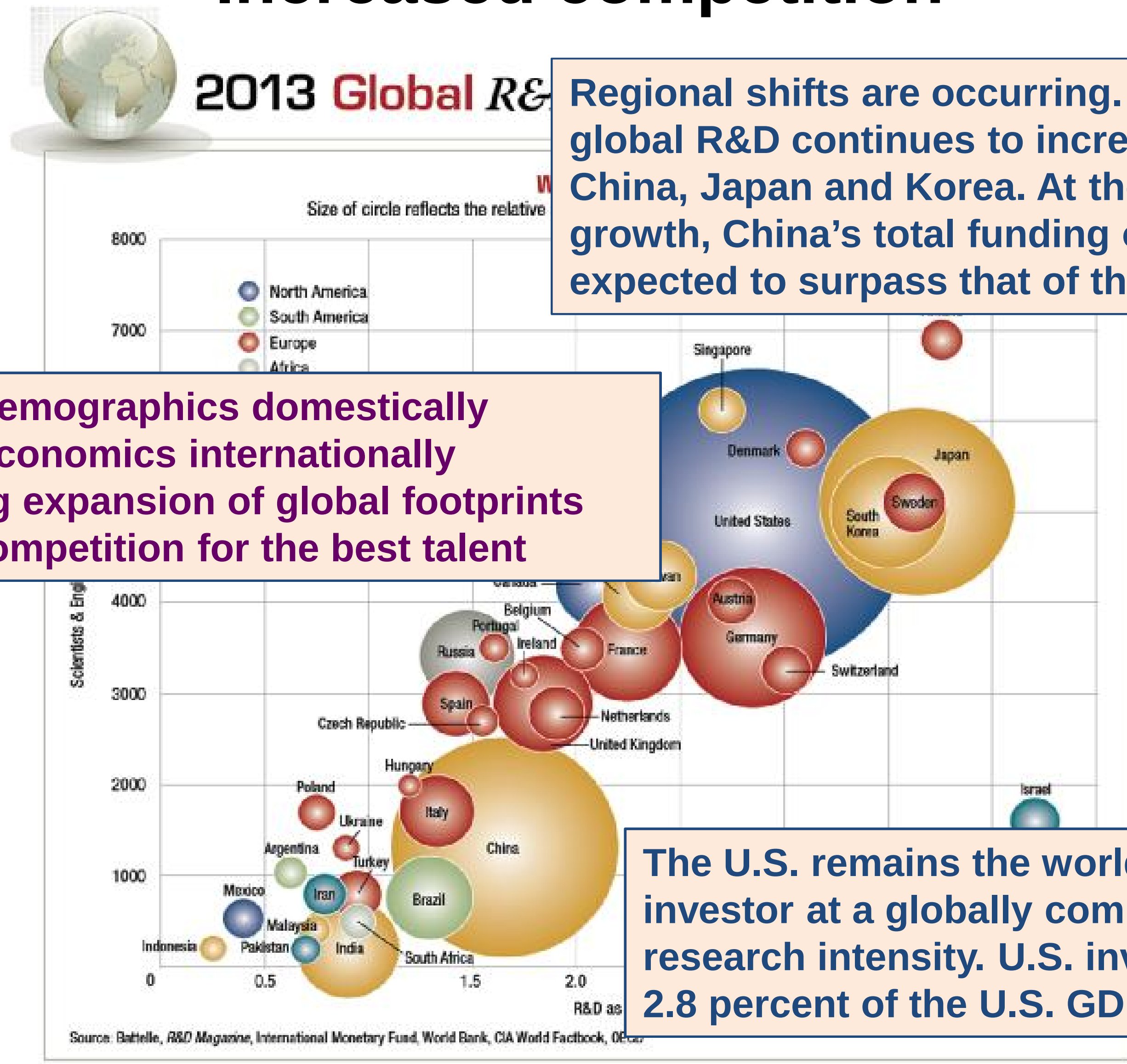
Research, Innovation and Economic Growth

Point #1

We are in a period of rapid and profound social, economic, and technological transformation accentuated by relentless global competition.

Our R&D investments does not match our global economic aspirations nor national security rhetoric.

Borderless knowledge enterprise and Increased competition

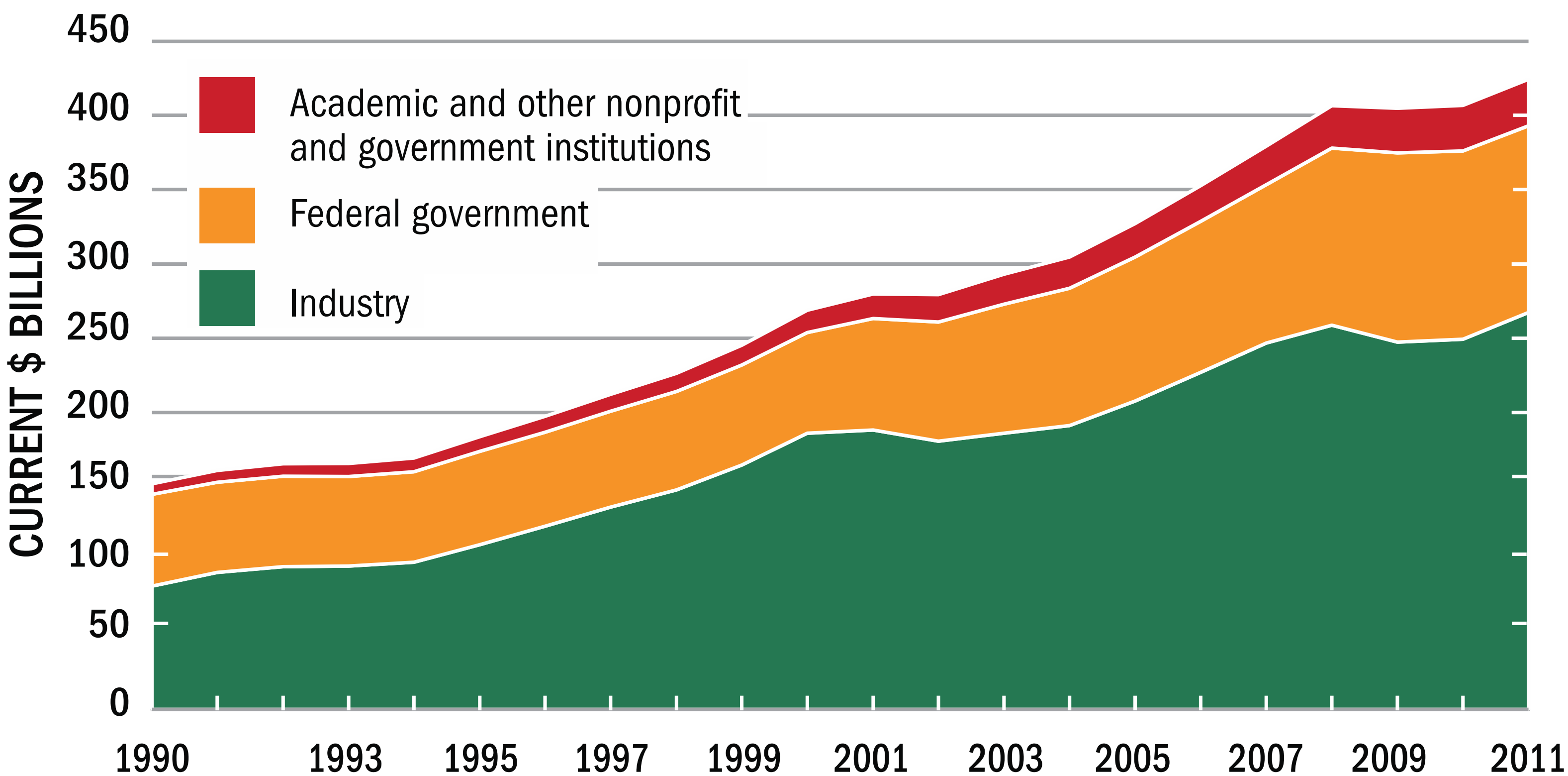


Regional shifts are occurring. Asian share of global R&D continues to increase, driven by China, Japan and Korea. At the current rates growth, China's total funding of R&D is expected to surpass that of the U.S. by 2022.

- **Shifting demographics domestically**
- **Shifting economics internationally**
- **Increasing expansion of global footprints**
- **Intense competition for the best talent**

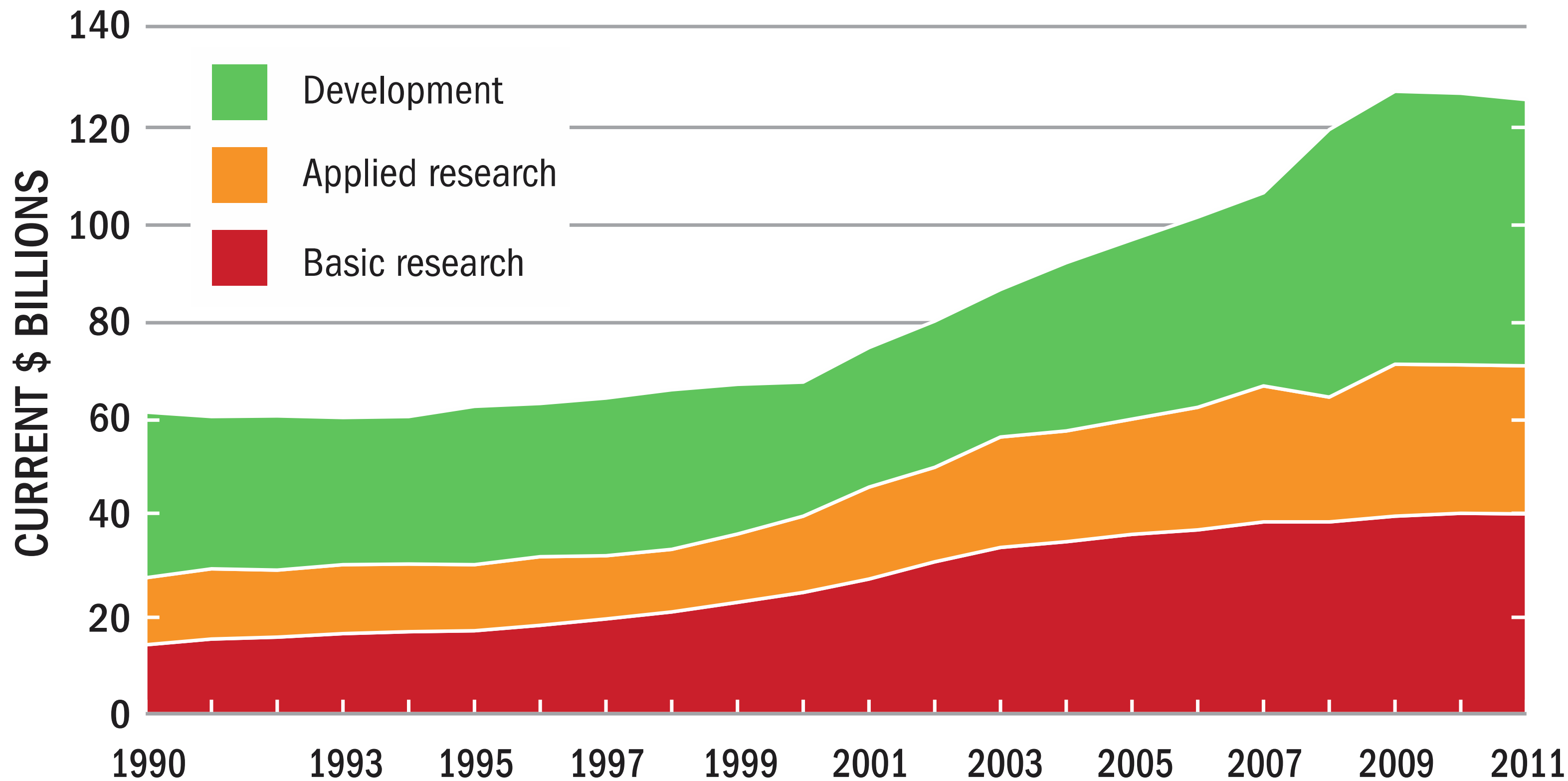
The U.S. remains the world's largest R&D investor at a globally competitive level of research intensity. U.S. investments are 2.8 percent of the U.S. GDP.

U.S. R&D expenditures, by source of funds: 1990–2011



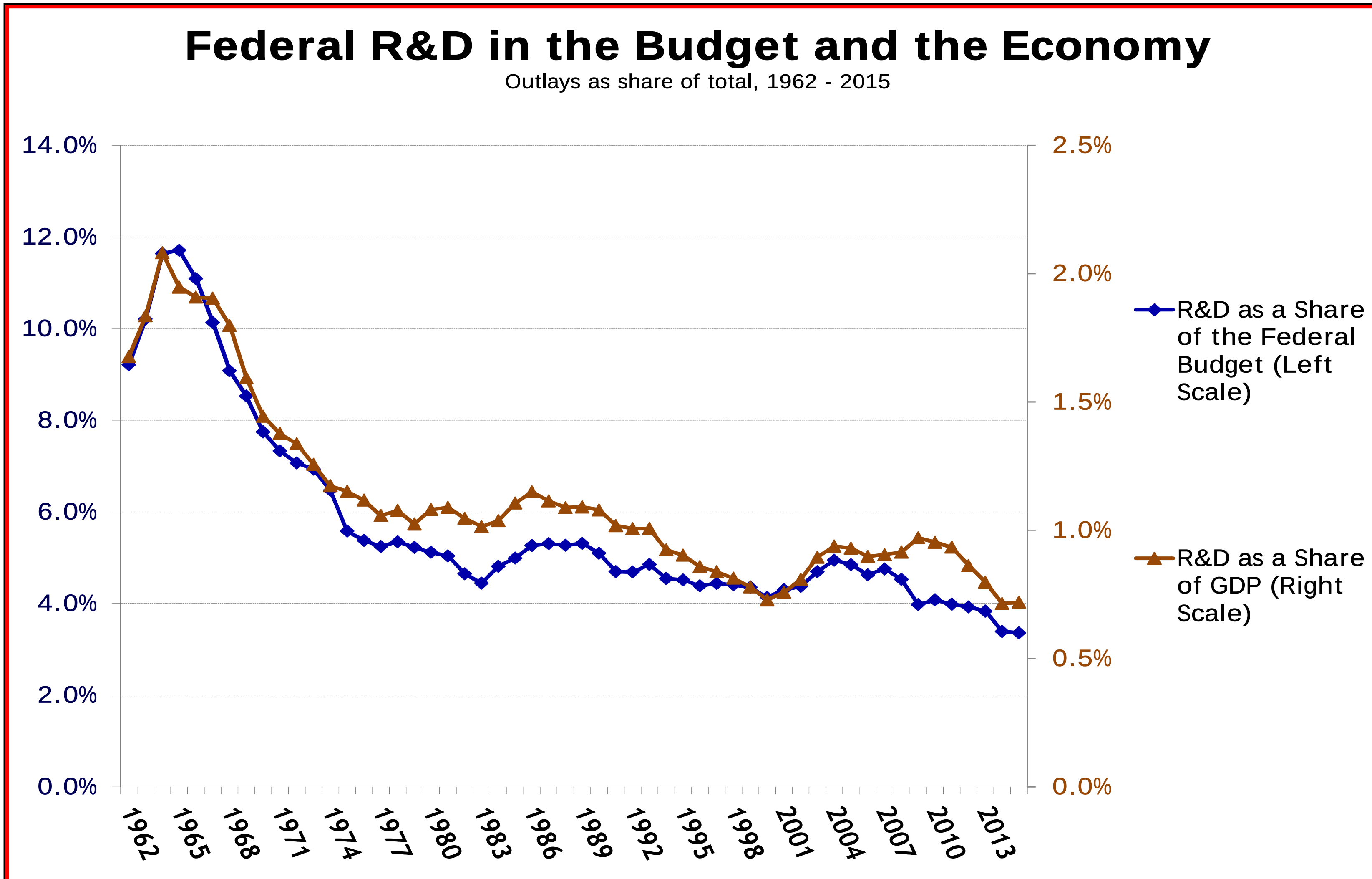
SEI 2014: **Sources of R&D Funding**, Chapter 4.

Federal R&D funds, by type of work: 1990–2011

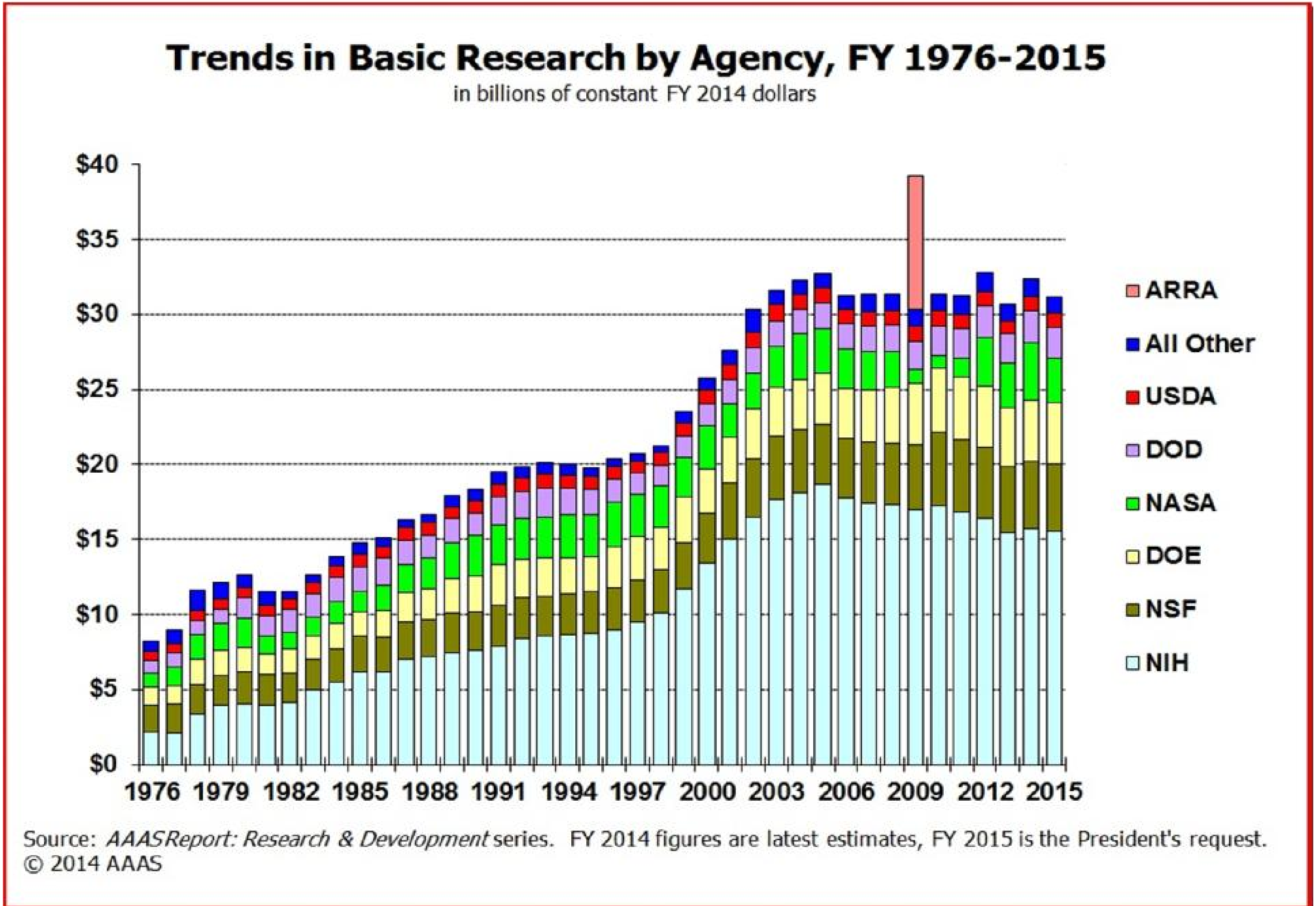


SEI 2014: **R&D, by Character of Work**, Chapter 4.

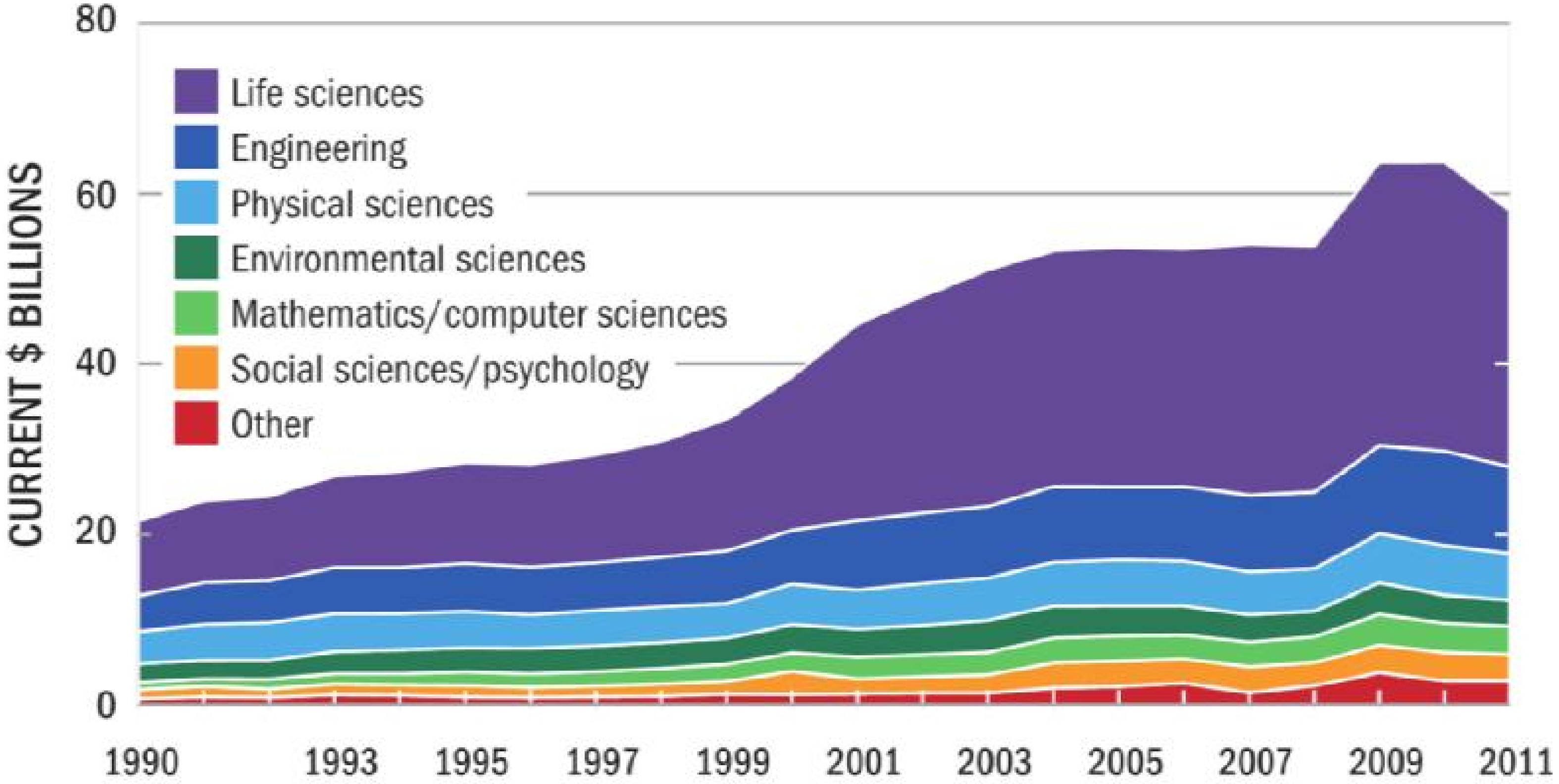
Flat or No Growth in Federal Research Budget



Source: *Budget of the United States Government, FY 2015.* FY 2015 is the President's request. © 2014 AAAS


Trends in Basic Research by Agency, FY 1976-2015
in billions of constant FY 2014 dollars
$40
$35
$30
$25
$20
$15
$10
$5
$0
1976 1979 1982 1985 1988 1991 1994 1997 2000 2003 2006 2009 2012 2015
ARRA
All Other
USDA
DOD
NASA
DOE
NSF
NIH
Source: *AAAS Report: Research & Development* series. FY 2014 figures are latest estimates, FY 2015 is the President's request.
© 2014 AAAS

Federal basic and applied research funds, by S&E field: 1990–2011



Science and Engineering Indicators 2014: **Federal Spending on Research, by Field**, Chapter 4.

NSF CISE FY 2014 Selected Cross-cutting Programs: Success Rates

Program	Proposals	NSF Awards	Success Rate
NRI	332	36	10.84%
Big Data	392	38	9.69%
Smart Health	292	21	6.91%
CPS	392	63	16.07%
SaTC	519	100	19.27%

Credit: Jim Kurose, AD, CISE Directorate, NSF.
Excludes supplements, workshops, CAREER awards.

Point #2

A thriving basic research community is the foundation for long-term discovery and innovation, economic prosperity and national security.

Paradox of Discovery and Innovation: no one knows how an idea or invention will impact the world until it is widely used, leading to unintended consequences.

Long-Term Investment in Basic Research is Imperative

- There is often a **long, unpredictable incubation period** – requiring sustained investment – between initial exploration and impact.
- Interactions of research ideas **multiply their impact** and **seed new ideas** with the potential to lead to unanticipated advances.
- **Unanticipated outcomes** are often as important as the anticipated ones.

A Long History of Federal R&D Investments

- The US taxpayer has long been the most important investor in knowledge creation

- Implementation of Vannevar Bush's 1945 report to the President on public investments in basic and applied research: funding universities $450M in defense contracts

- Today's Silicon Valley w/ "freewheeling entrepreneurs and visionary VCs" was defense valley for 30 years sustained by policies and investment priorities of Cold War
  - Spinoffs: **Shockley Transistor Corp à Fairchild Semiconductor à Intel**

- NSF and DARPA's funding of CS departments in the 60s and 70s

- Decades of investments led to the creation of **scientific knowledge underlying the pharma-biotech industry**: Orphan Drug Act of 1993

- **DARPAnet and NSFnet à Today's Internet**

- Small Business Research Innovation (SBIR) Program based on a pilot from NSF in 1980s (1.25% research funding to small independent businesses)

What's the Role Federal Government?

- Since the Founding Fathers, the US has always had to balance two views, the activist view of Alexander Hamilton and Thom… …efferson's position that "the government that governs least, go… …"

- American pragmatism: *"The Jeffersoni… …and the Hamiltonians in charge of po…*

  -- *The…*

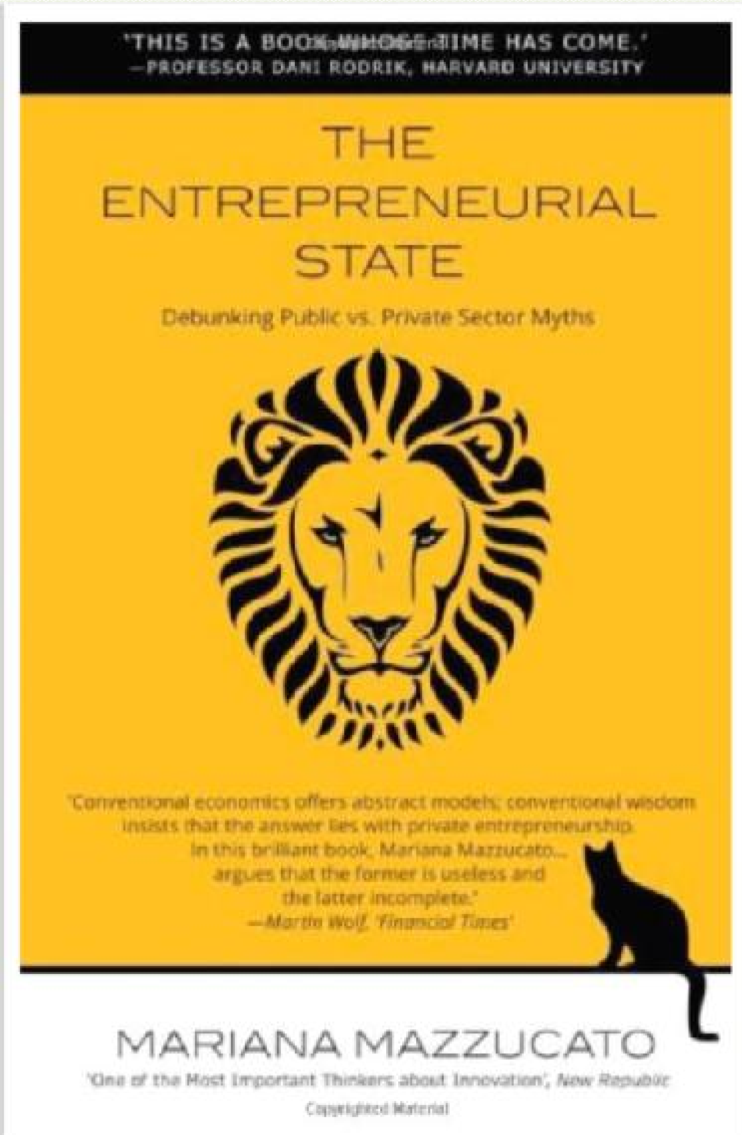
- Not just the s… …oping an innovation ecosyst…

- Many h… …aving a national ecosystem of innovatio… …ficient or even possible without the "State" plays a m… …the ecosystem.

- Government investments in areas that increase nation's capacity for innovation: education, research and infrastructure.

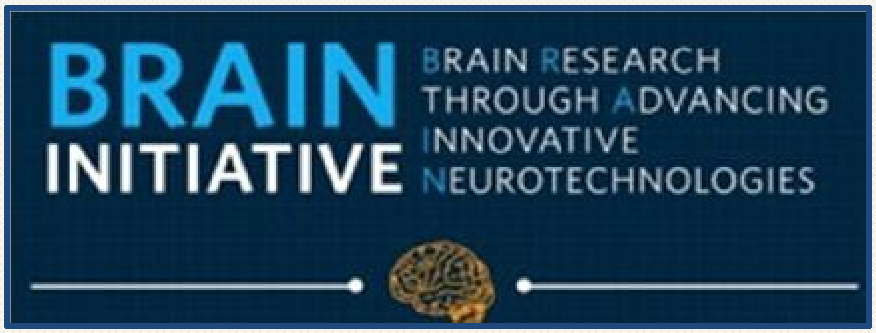
Federal Government as a Risk Taker and Market Shaper!

Entrepreneurial State



- Knowledge creation through sponsorship of basic and applied research, education and infrastructure
- Active supply-side or demand-side (industrial) policies to drive private sector innovation in pursuit of broad public policy goals
- Actively “picking winners” – by targeting resources and by brokering public-private partnerships to foster innovation and economic growth

Examples of National Initiatives



The National Robotics Initiative (NRI)

Federal Big Data R&D Initiative

Materials Genome Initiative

Point #3

Universities continue to play a growing and central role in the innovation ecosystem driving economic growth.

The ability to relate research outcomes to transformative economic development will continue to be a fundamental driver shaping support for research investments.

Technology Transfer Mechanisms
(an academic perspective)

- Knowledge creation and dissemination
  - Students entering the job market
  - Publications in scientific journals and conferences
  - Faculty advising government and industry
- License patented technologies, software and hardware prototypes
- Seed technology for startups

Association of University Technology Managers (AUTM)

- The universities participating in the AUTM survey reported a total of 4200 operating university start-ups as of 2013 nearly double the number operating in 2000. What is more, in 2003 universities initiated 330 start-ups; the number last year was 818 in 2013.

Bayh-Dole Act (1980)

- In 1980 Congress enacted the Bayh-Dole Act, intended to promote the development of technologies arising from

> **"Don't worry about people stealing an idea. If it's original, you'll have to ram it down their throats."**
>
> **-- Computing Pioneer Howard Aiken**

- them with using the patent system to encourage disclosure and commercialization of the inventions.

Why Commercialize University Technologies?

- Public benefit and fulfillment of the university's larger missions
  - Transfer to commercial sector for public benefit
  - Significant gap between research prototype and general availability of a solution

- Qualitative impact on the institution
  - Enhances faculty and student recruitment
  - Enhances national visibility
  - Supports academic mission

often exaggerated

- Direct financial incentives for universities?
  - Potential upside from licensing agreements
  - Isolated instances do not support a business cas

often overlooked

- Regional and national economic impact
- Increased in sponsored research and philanthropy

A Shift in Thinking

- Technology transfer from universities is NOT about *protection* of intellectual of property created in research laboratories

- It is about
  - Knowledge ***dissemination***
  - Economic ***development***
  - Societal ***benefit***

- It is about making our universities play a central role in the *innovation ecosystem* driving economic growth.

Focus on Return on Investment (ROI)

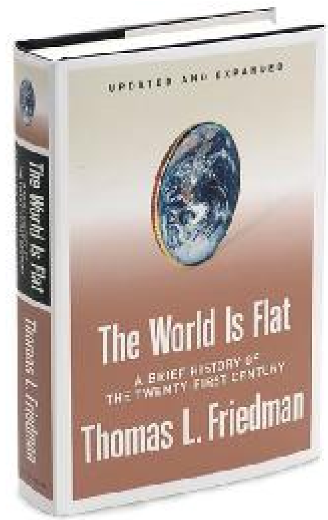
- Research investment is not just risky; it is highly uncertain.
- How do you assign probability to “serendipity” and “unexpected outcomes”?
- Return from research investments are highly uncertain and cannot be explained thru rational economic theory.
- The “high risk and serendipitous characteristics of the innovation process is one of the reasons why profit-maximizing companies invest less in basic research.”

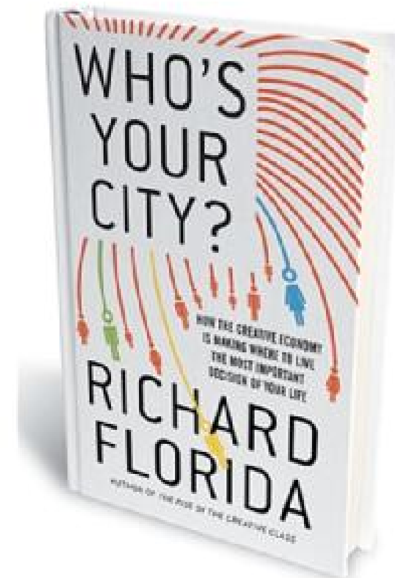
The World Is *Not* Flat … It Is Spiky

- Thomas Friedman argues that the global economic playing field has been leveled … and anyone can innovate, produce and compete on a par with workers in Seattle or entrepreneurs in Silicon Valley

- Urban theorist Richard Florida in his 2009 book, Who's Your City, takes a contrary position, arguing that the "World is Spiky."

- We see a *clustering force* in play, resulting in highly localized distribution of GDP, patent applications, innovation, top scientists, etc. in connected mega-regions across the world.





Globalization vs.
the Knowledge Economy

Two Sides of Globalization and Economic Growth

- Geographical distribution of routine economic activities – such as manufacturing and call center services – and expansion of consumer market across the world.

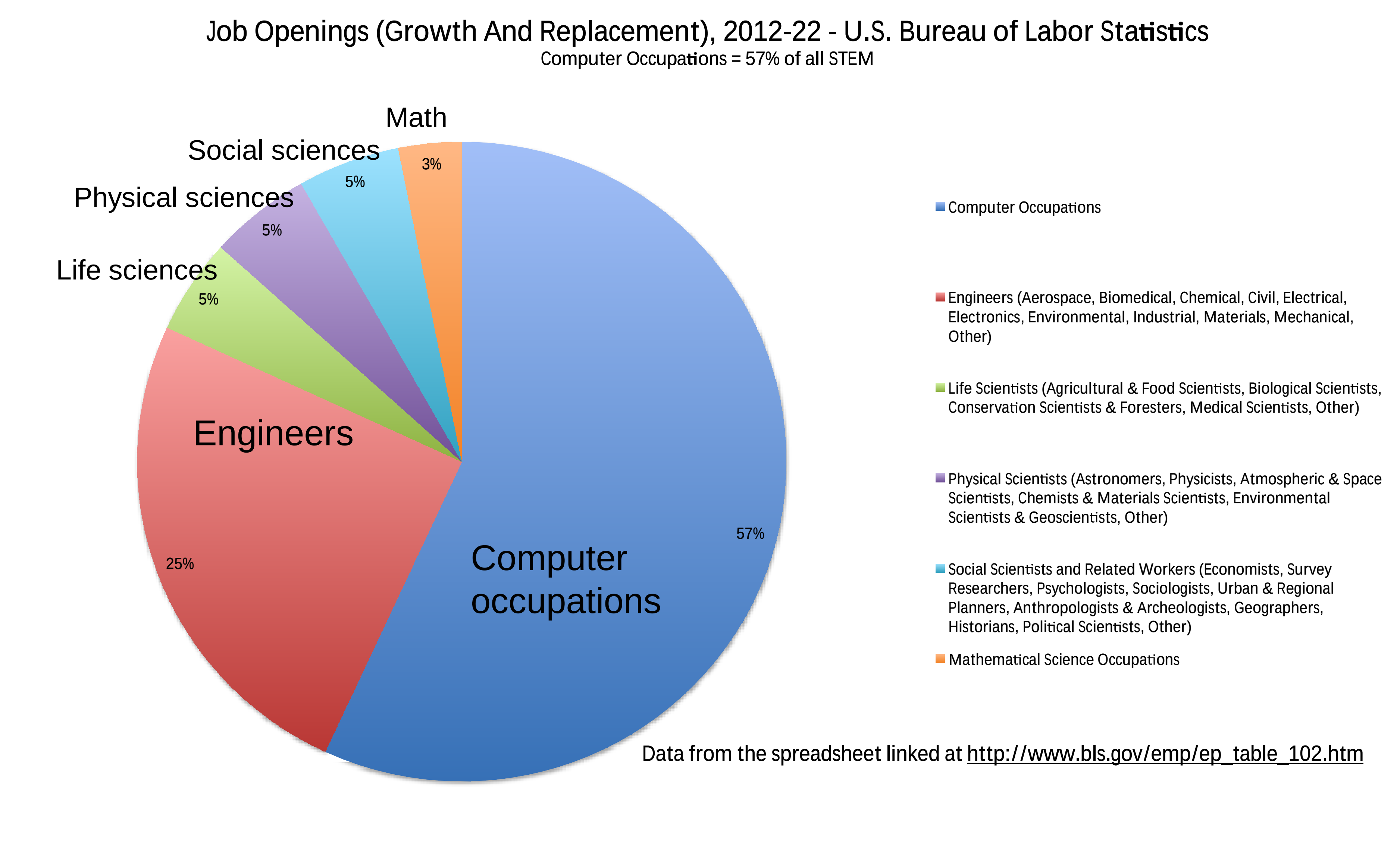
- ***Economic Expansion****:* increasing the volume of ordinary economic output – revving up the production of an assembly line.

- Clustering of higher-level economic activities – such as engineering innovation, design, finance, and media – around talents and creative skills in mega-regions and centers.

- ***Economic Development****:* economic growth stemming from innovation and creative work.

The reality of globalization is that the world is flat and spiky at the same time: valleys between interconnected peaks.

STEM Job Growth



The Growing Imperative of Research and Education

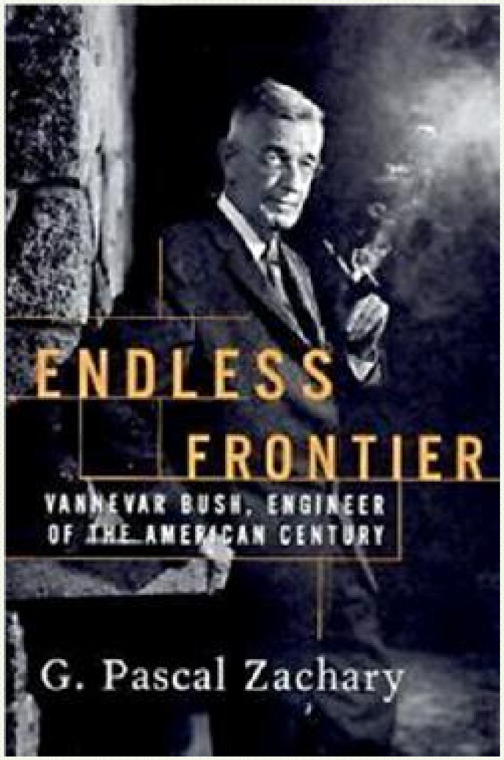
- Our investments in **research** and **education** have returned exceptional dividends to our nation.

- A thriving basic research community is the foundation for long-term discovery and innovation, **economic prosperity**, and **national security**.

- As a field of inquiry, computer, communication and information science and engineering has a **rich intellectual agenda** – highly creative, highly interactive, with enormous possibilities for changing the world!

Vannevar Bush's Vision of the Endless Frontier

Basic research is *"the pacemaker of technological progress"* and *"[n]ew products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science!"*



Thanks!

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Emerging Frontiers

Data Explosion

Smart Systems and Robotics

Expanding the Limits of Computation

Secure Cyberspace

Universal Connectivity

Augmenting Human Capabilities