Unleashing the Discovery and Innovation Ecosystem

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“Innovation distinguishes between a leader and a follower” – Steve Jobs, 2005

“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

- Universities and research labs
- Public-private partnerships
- Venture capital
- Infrastructure
- Government investments
- Scientists and engineers
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)

- Mobile Internet
- Automation of knowledge work
- The Internet of Things
- Cloud technology
- Advanced robotics
- Autonomous and near-autonomous vehicles
- Next-generation genomics
- Energy storage
- 3D printing
- Advanced materials
- Advanced oil and gas exploration and recovery
- Renewable energy

SOURCE: McKinsey Global Institute analysis
Research, Innovation and Economic Growth
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.

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

Federal R&D in the Budget and the Economy
Outlays as share of total, 1962 - 2015

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

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

<table>
<thead>
<tr>
<th>Program</th>
<th>Proposals</th>
<th>NSF Awards</th>
<th>Success Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRI</td>
<td>332</td>
<td>36</td>
<td>10.84%</td>
</tr>
<tr>
<td>Big Data</td>
<td>392</td>
<td>38</td>
<td>9.69%</td>
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<tr>
<td>Smart Health</td>
<td>292</td>
<td>21</td>
<td>6.91%</td>
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<tr>
<td>CPS</td>
<td>392</td>
<td>63</td>
<td>16.07%</td>
</tr>
<tr>
<td>SaTC</td>
<td>519</td>
<td>100</td>
<td>19.27%</td>
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</tbody>
</table>

Credit: Jim Kurose, AD, CISE Directorate, NSF.
Excludes supplements, workshops, CAREER awards.
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 ⇄ Fairchild Semiconductor ⇄ 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 ⇄ 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 Thomas Jefferson’s position that “the government that governs least, governs best.”

• American pragmatism: “The Jeffersonians in charge of the rhetoric and the Hamiltonians in charge of policy.”
  -- The Entrepreneurial State by Mariana Mazzucato

• Not just the size of R&D expenditures, rather developing an innovation ecosystem.

• Many have argued that simply having a national ecosystem of innovation would not be sufficient or even possible without the “State” playing a major role in shaping the ecosystem.

• Government investments in areas that increase nation’s capacity for innovation: education, research and infrastructure.
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
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
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.
In 1980 Congress enacted the Bayh-Dole Act, intended to promote the development of technologies arising from federally funded research by permitting licensing agreements between research entities and for-profit companies. The Bayh-Dole Act explicitly gave universities and research institutions title to federally-funded inventions and charged them with using the patent system to encourage disclosure and commercialization of the inventions.

“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
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

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

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

*often exaggerated*

*often overlooked*
A Shift in Thinking

• Technology transfer from universities is NOT about *protection* of intellectual 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

Job Openings (Growth And Replacement), 2012-22 - U.S. Bureau of Labor Statistics
Computer Occupations = 57% of all STEM

- Computer Occupations
- Engineers (Aerospace, Biomedical, Chemical, Civil, Electrical, Electronics, Environmental, Industrial, Materials, Mechanical, Other)
- Life Scientists (Agricultural & Food Scientists, Biological Scientists, Conservation Scientists & Foresters, Medical Scientists, Other)
- Physical Scientists (Astronomers, Physicists, Atmospheric & Space Scientists, Chemists & Materials Scientists, Environmental Scientists & Geoscientists, Other)
- Social Scientists and Related Workers (Economists, Survey Researchers, Psychologists, Sociologists, Urban & Regional Planners, Anthropologists & Archeologists, Geographers, Historians, Political Scientists, Other)
- Mathematical Science Occupations

Data from the spreadsheet linked at http://www.bls.gov/emp/ep_table_102.htm
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