Research and Policy: *A View from NSF*

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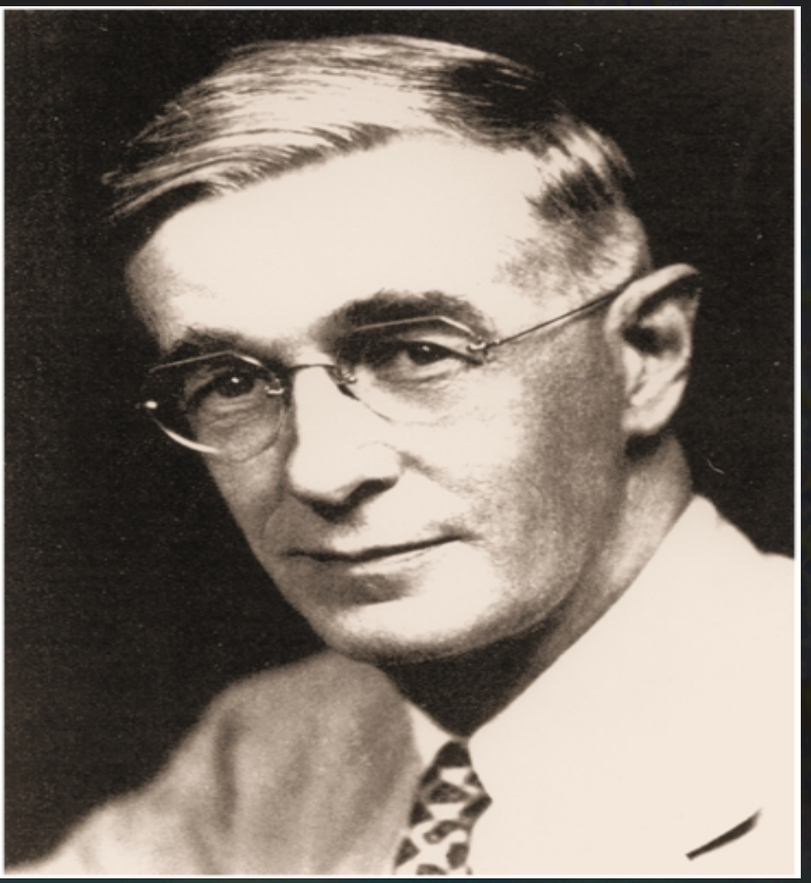
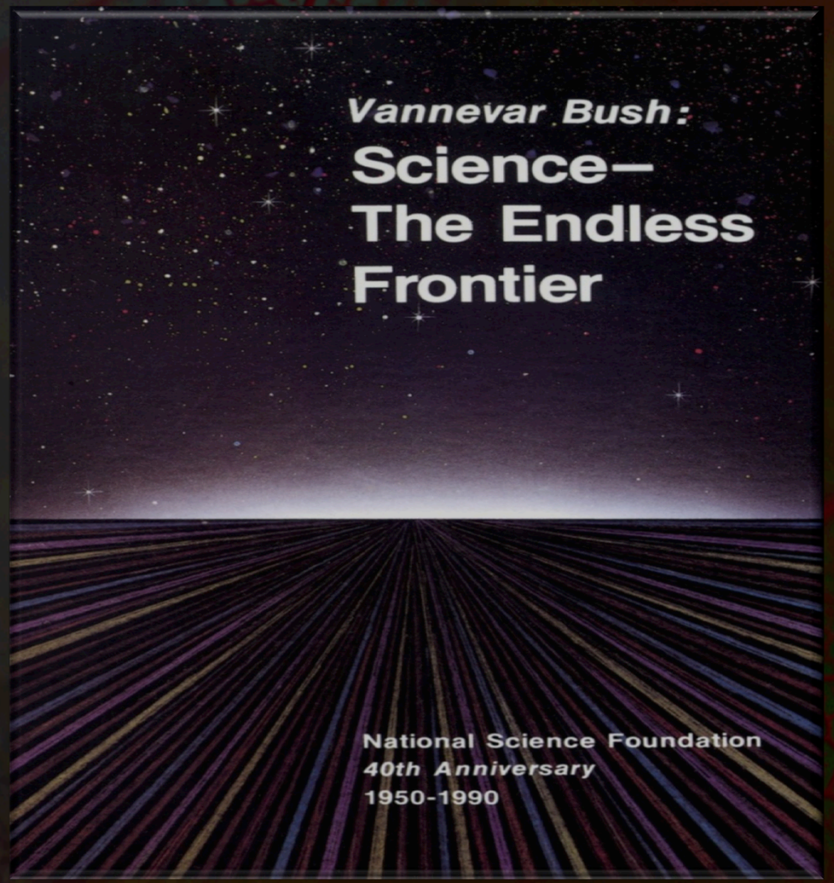
CaltechAugust 6, 2014



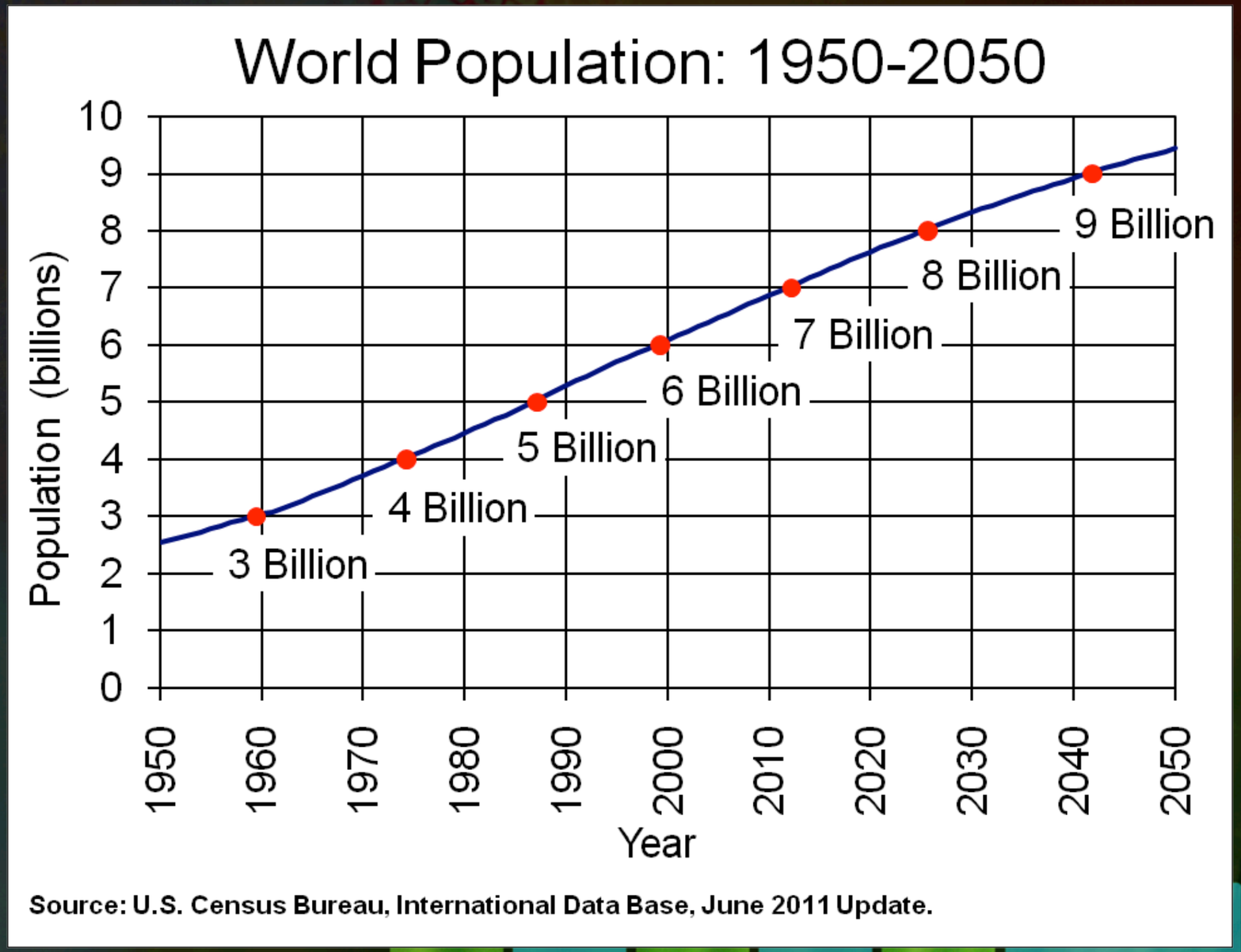


Science offers a largely unexplored hinterland for the pioneer who has the tools for his task. The rewards of such exploration both for the Nation and the individual are great. Scientific progress is one essential key to our security as a nation, to our better health, to more jobs, to a higher standard of living, and to our cultural progress..

"to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…" NSF Act, 1950

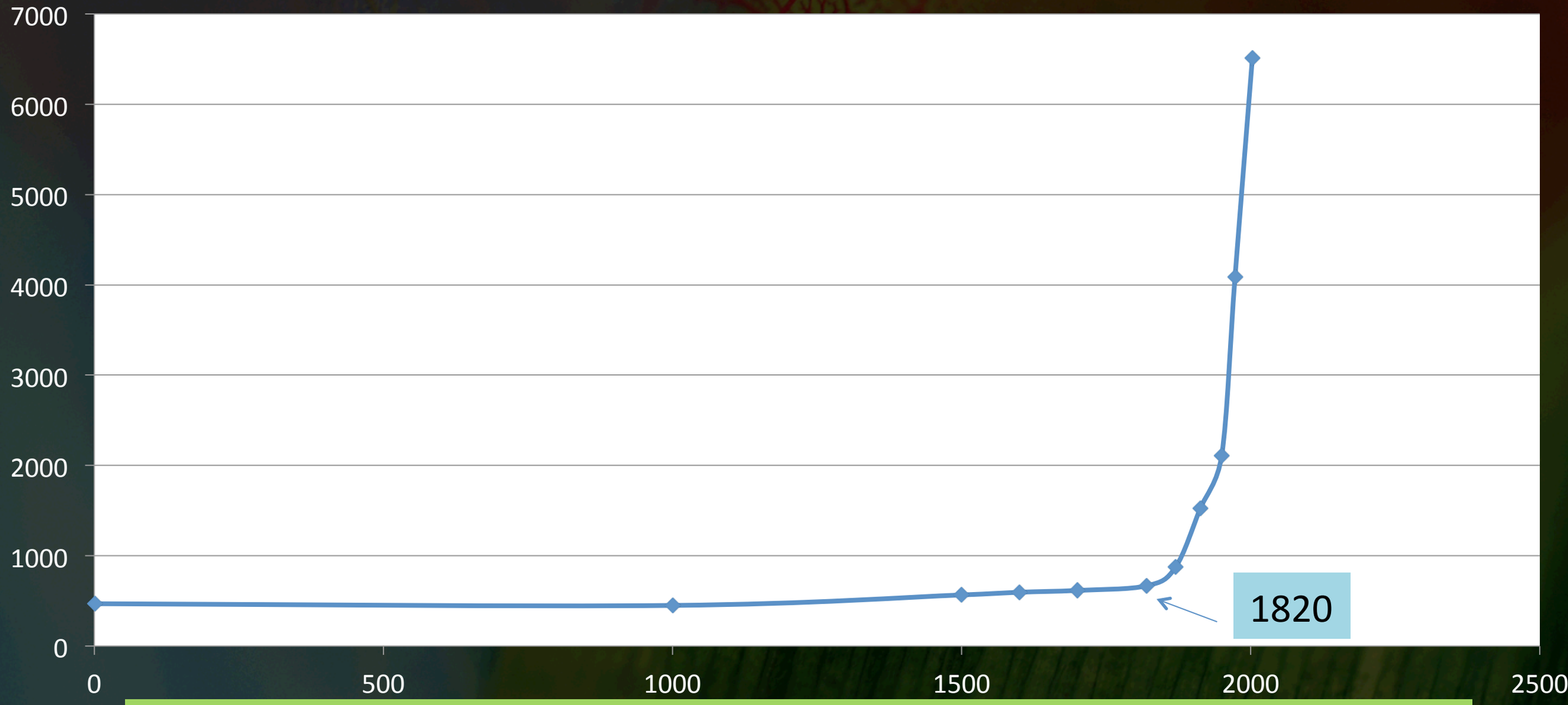
Image courtesy MIT Museum

World Population



9.6 Billion by 2050
400 Million in US

World GDP per capita (1 – 2003)

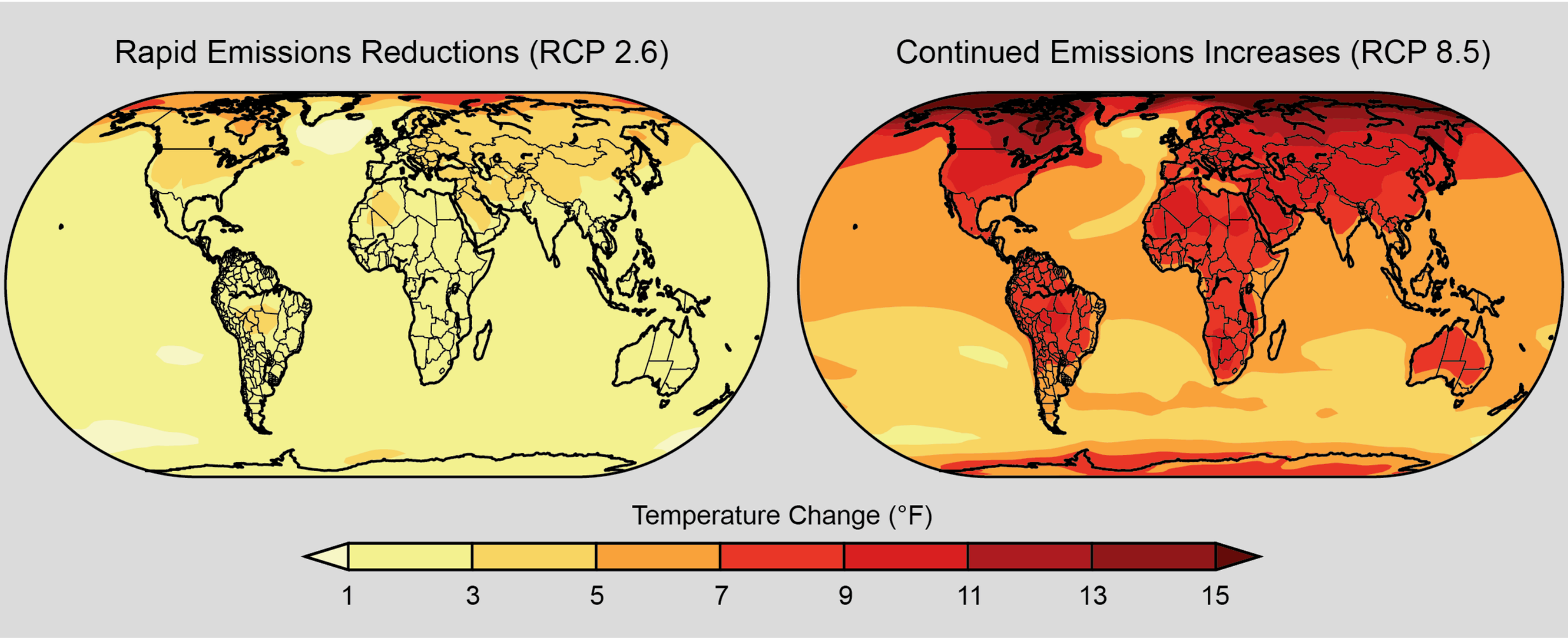


Source: A. Maddison, World Economy, 2007

"Hockey-stick" growth starting with the industrial revolution

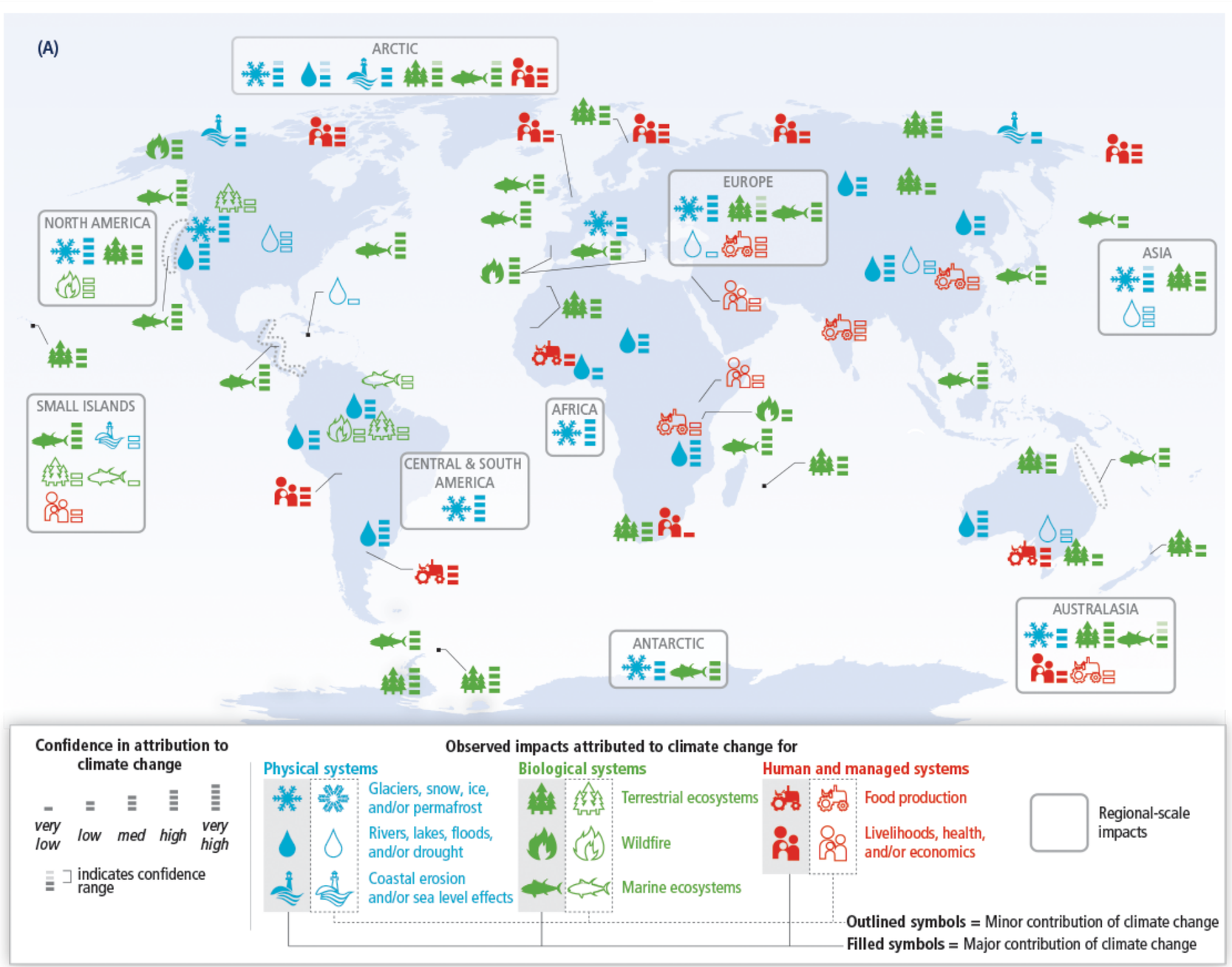
Climate Change

Projected Change in Average Annual Temperature



Source: Walsh, J., D. Wuebbles, K. Hayhoe, J. Kossin, K. Kunkel, G. Stephens, P. Thorne, R. Vose, M. Wehner, J. Willis, D. Anderson, S. Doney, R. Feely, P. Hennon, V. Kharin, T. Knutson, F. Landerer, T. Lenton, J. Kennedy, and R. Somerville, 2014: Ch. 2: Our Changing Climate. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 19-67. doi:10.7930/J0KW5CXT. Available at http://nca2014.globalchange.gov/report/our-changing-climate/future-climate-change

Impacts of Climate Change



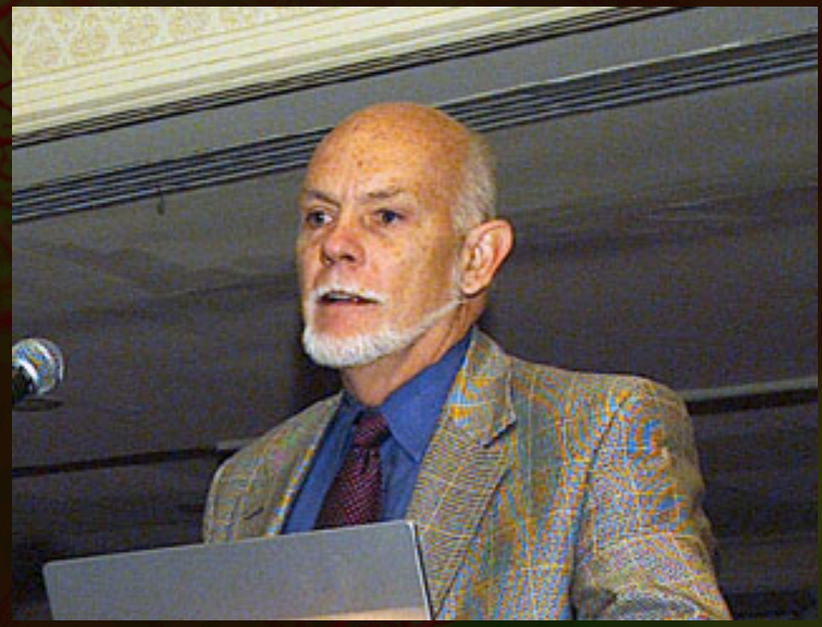
Source: Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Figure SPM.2A

Key Questions

- Can we raise the standard of living of the world population to an acceptable level and achieve sustainability?
- What are the limits to economic growth from sustainability constraints?
- How can we get to full employment, high quality of life, and sustainable development?

Smalley's List of Top 10 Problems

- Energy
- Water
- Food
- Environment
- Poverty
- Terrorism and War
- Disease
- Education
- Democracy
- Population



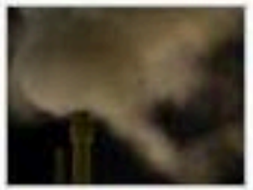
Richard Smalley
Our Energy Future, 2003

Image courtesy Oak Ridge National Laboratory

National Academy of Engineering

Make solar energy economical

Provide energy from fusion



Develop carbon sequestration methods

Manage the nitrogen cycle

Provide access to clean water

Restore and improve urban infrastructure

Advance health informatics

Engineer better medicines

Reverse-engineer the brain

Prevent nuclear terror

Secure cyberspace

Enhance virtual reality

Advance personalized learning

Engineer the tools of scientific discovery

Image courtesy National Academy of Engineering

Role of Grand Challenges

- Grand challenges can be very useful in catalyzing major breakthroughs and advances
- Key characteristics:
  - Big impact
  - Ambitious yet achievable
  - Compelling vision
  - Right level of specificity

Imagining the Future of Engineering

- Vital and essential role for engineering to enable a prosperous, secure, healthy and sustainable society
- Ambitious, specific, but achievable grand challenges to stimulate the imagination, creativity, and ingenuity leading to dramatic advances
- Seamless transitions and feedback loops between fundamental research and practical realizations leading to great innovations
- Engineering education innovations to overcome stubborn, long-standing problems in retention, diversity, and K-12 and attract highly talented people to the profession

Major Trends and Forces

- Ubiquitous computing and communications
  - Computational modeling, data, simulation, optimization pervasive in all fields of engineering
  - Networks and computation deeply integrated into engineered systems
  - Machine intelligence
- Systems science and engineering
  - Multi-scale analysis, design, and optimization
  - Integration of physical and cyber components
  - Range: nano- to micro- to macro-scale
  - Scale and complexity: large numbers of components
  - Safety, robustness, resilience, …

Major Trends and Forces

- Nanoscale science and technologies
  - Improving understanding and new tools at the atomic and molecular scales
  - Progressing from passive components to active systems and design
- Biological/Medical
  - Interaction of engineered systems and biology at all scales – DNA to cells to organs to organisms to eco-systems
  - Engineering for neuroscience and brain
  - Synthetic biology
  - Plants, food, and agriculture
  - Advanced biomanufacturing
  - Biologically inspired engineering

Major Trends and Forces

- Behavioral/economic/cognitive sciences
  - Human behavior and game theory in engineered systems and technology design
  - Prominent role in infrastructure systems such as electric grid, transportation, water, gas
  - Economic, regulatory, policy issues
- Design, *creativity, aesthetics, …*

System - Definitions

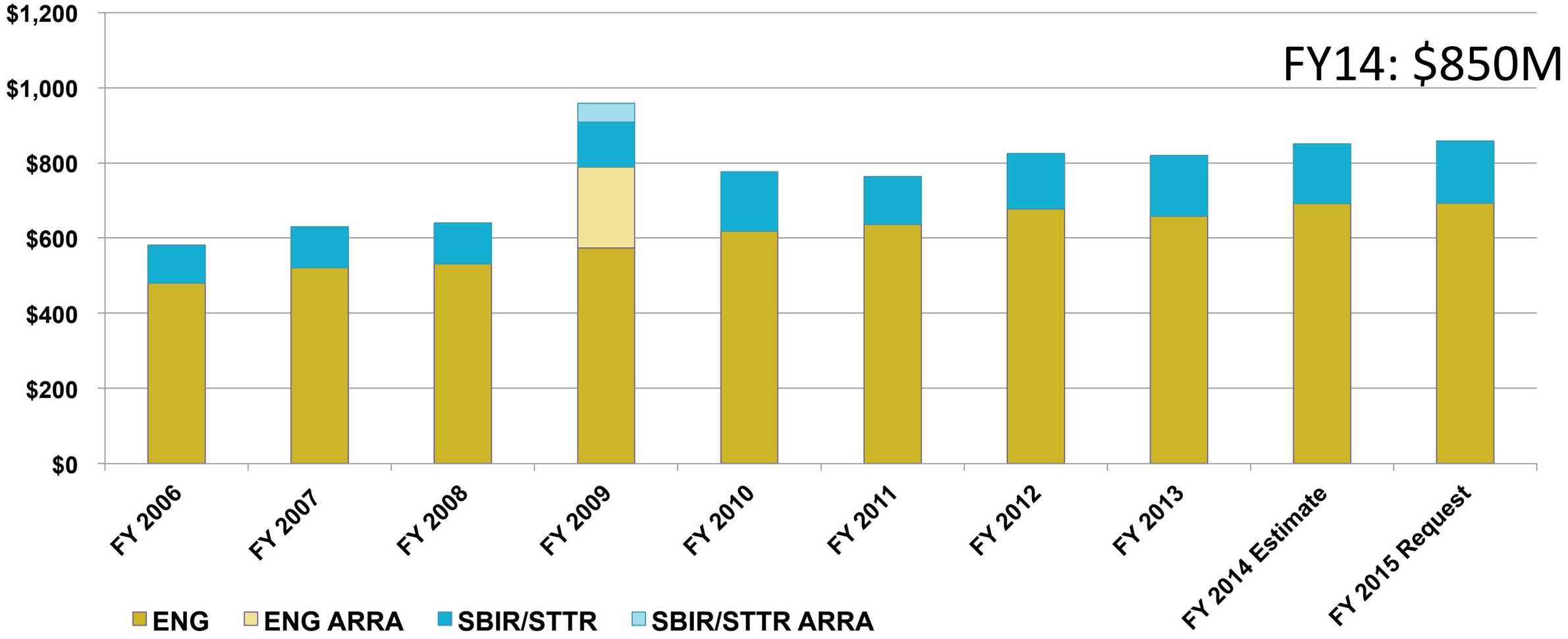
- Set of connected things or parts forming a complex whole, in particular
  - A set of things working together as parts of a mechanism or an interconnecting network
  - A set of organs in the body with a common structure or function
  - Human or animal body as a whole
  - A group of related hardware units or programs or both, especially when dedicated to a single application
  - Geology (in chronostratigraphy) a major range of strata that corresponds to a period in time, subdivided into series
  - Astronomy a group of celestial objects connected by their mutual attractive forces, especially moving in orbits about a center
  - Each of seven categories of crystals (cubic, tetragonal, orthorhombic, trigonal, hexagonal, monoclinic, and triclinic) classified according to the possible relations of the crystal axes
- Set of principles or procedures according to which something is done; an organized scheme or method:
  - Orderliness - method
  - Method of choosing one's procedure in gambling
  - Set of rules used in measurement or classification
  - The prevailing political or social order, especially when regarded as oppressive and intransigent
- *From Oxford English Dictionary*

One of 1000 most-used words

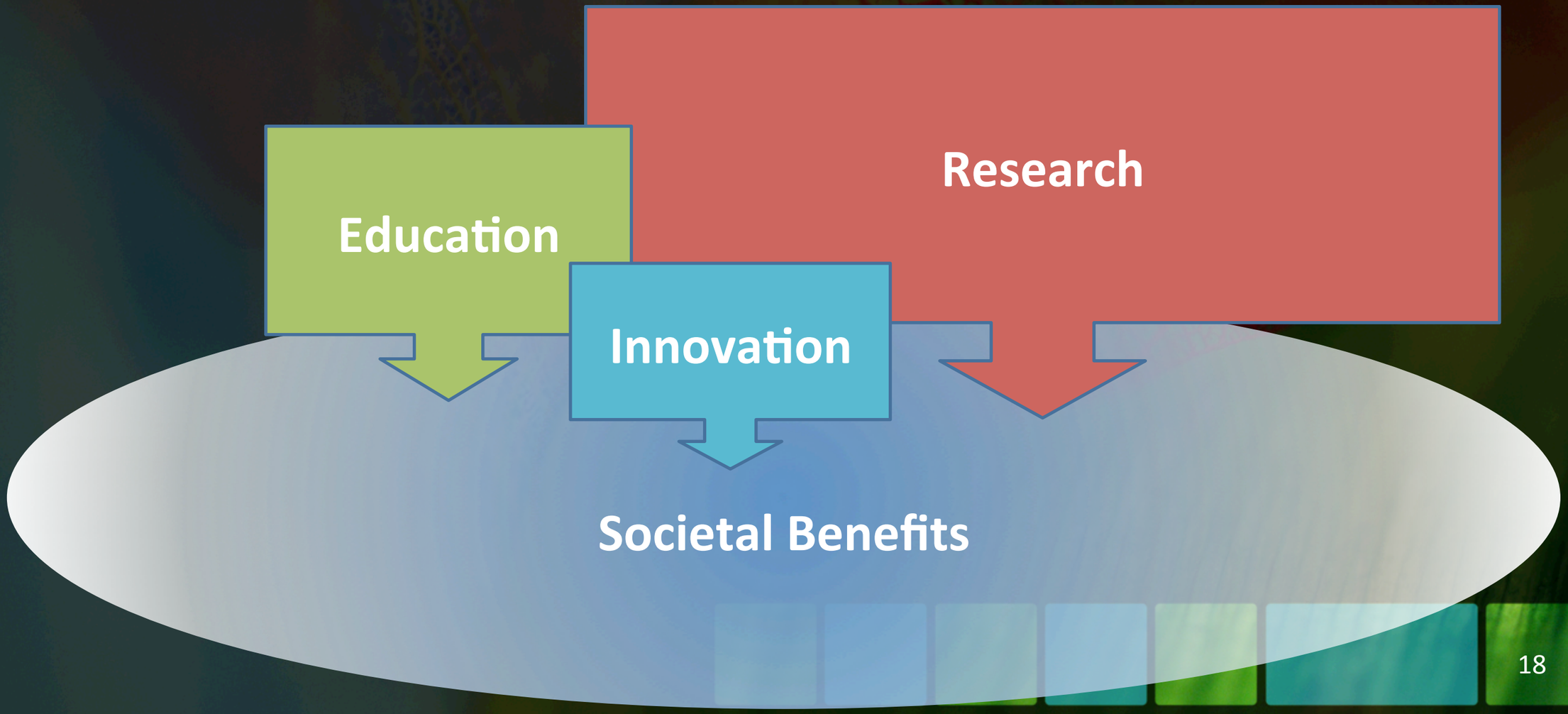
Systems – *Ubiquitous at NSF*

- Systems is a common theme in all divisions in ENG
  - CBET, CMMI, ECCS, EEC, and IIP
- Systems oriented work is supported in CISE:
  - Computer and Network Systems
  - Information and Intelligent Systems
- Systems in several other NSF directorates:
  - Social and Behavioral Sciences
  - Biological Sciences
  - Mathematical and Physical Sciences
  - Geological Sciences

ENG and SBIR/STTR R&RA Budgets ($M)



NSF ENG: Investing in engineering research and education to foster innovations for benefit to society



Engineering Directorate prioritizes research critical to the Nation's challenges

- National Initiatives
  - Advanced Manufacturing
  - Clean Energy
  - National Nanotechnology Initiative
  - BRAIN

Core programs in various divisions play a critical role in addressing these priorities.

- NSF Cross-cutting Priorities
  - Cognitive Science and Neuroscience
  - Communications and Cyberinfrastructure (security, wireless spectrum)
  - Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS)
  - Science, Engineering, and Education for Sustainability (SEES)
  - Education and Career Development
  - Interdisciplinary Research
  - Research Centers
  - Innovation Corps

Federal Research Funding – Key Players

- Executive Branch
- Legislative Branch
- Judicial Branch
- Non-government organizations
  - Industry
  - Non-profits

Executive Branch - EOP

- White House – Executive office of the President
- Office of Science and Technology Policy (OSTP)
- Office of Management and Budget (OMB)
- National Science and Technology Council (NSTC)
- Presidential Council of Advisors on Science and Technology (PCAST)
- Council of Economic Advisors (CEA)

OSTP

Broadly speaking, OSTP's work can be thought of as falling into four main topic areas:

Science

The Obama administration and the Office of Science and Technology Policy are committed to restoring science to its rightful place in America as a tool for crafting smart policies that will strengthen the nation. Learn more...

Technology & Innovation

In the face of unprecedented challenges, technological advances can provide a powerful engine for advancing economic growth and new opportunity. Learn more...

Environment & Energy

Of all the challenges we face as a nation and as a planet, none is as pressing as the three-pronged challenge of climate change, sustainable development and the need to foster new and cleaner sources of energy. Learn more...

National Security & International Affairs

New developments in science and technology (S&T) play a key role in predicting and addressing threats to our national and economic security and in meeting transnational priorities that improve the quality of life and global security. Learn more...

Image courtesy White House
http://www.whitehouse.gov/administration/eop/ostp

Executive Branch

- Federal Agencies
- Defense – AFOSR, ARO, ONR, DARPA, OSD
- Energy – BES, OE, EERE, FE, National Labs, Nuclear
- NASA
- Commerce - NIST
- NSF
- USDA, DoT, EPA, NSA, …

Legislative Branch

- House
- Senate
- Various committees govern science and engineering funding agencies
  - For NSF: House Science Committee, Senate Commerce, Science, and Transportation Committee
- House and Science Appropriations Committees
- Role of subcommittees
- Role of staffers

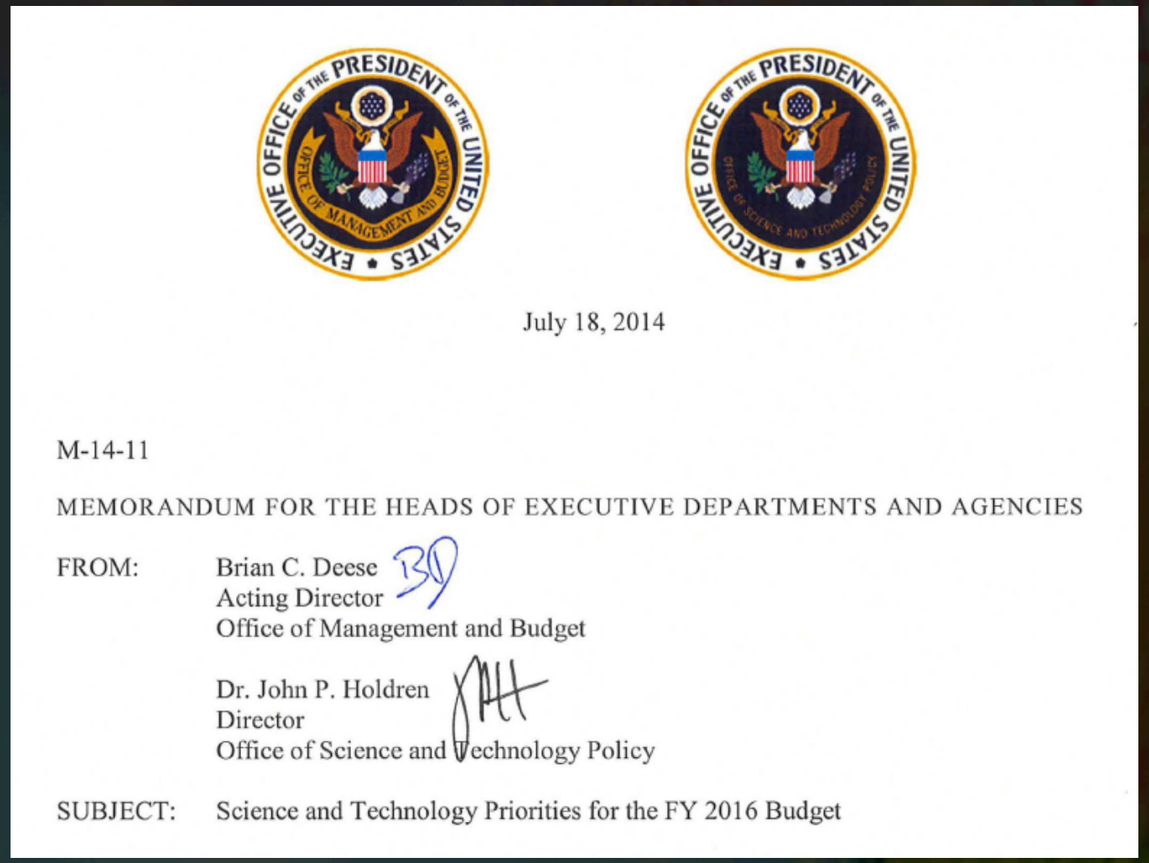
Non-Government Players

- Universities (AAU, APLU, …)
- Professional associations (APS, ACS, AGU, Business groups, IEEE, ASME, SIAM, …)
- Think tanks (Brookings, Pew, Wilson, Council on Competitivenes, Heritage, CAP, RAND, ITIF, and many many others)

Budget Cycle

- At any time, there are three budgets in play
  - FY 14 – making grants now
  - FY 15 – submitted to Congress in February 14
  - FY 16 – preparing now working with OSTP and OMB
- NSF Budget – *a proposal to Congress via EOP*

Budget Priorities



July 18, 2014

M-14-11

MEMORANDUM FOR THE HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

FROM: Brian C. Deese
Acting Director
Office of Management and Budget

Dr. John P. Holdren
Director
Office of Science and Technology Policy

SUBJECT: Science and Technology Priorities for the FY 2016 Budget

- Advanced manufacturing and industries of the future
- Clean energy
- Earth observations
- Global climate change
- Information technology and high-performance computing
- Innovation in life sciences, biology, and neuroscience
- National and homeland security

Source: M-14-11, MEMORANDUM FOR THE HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

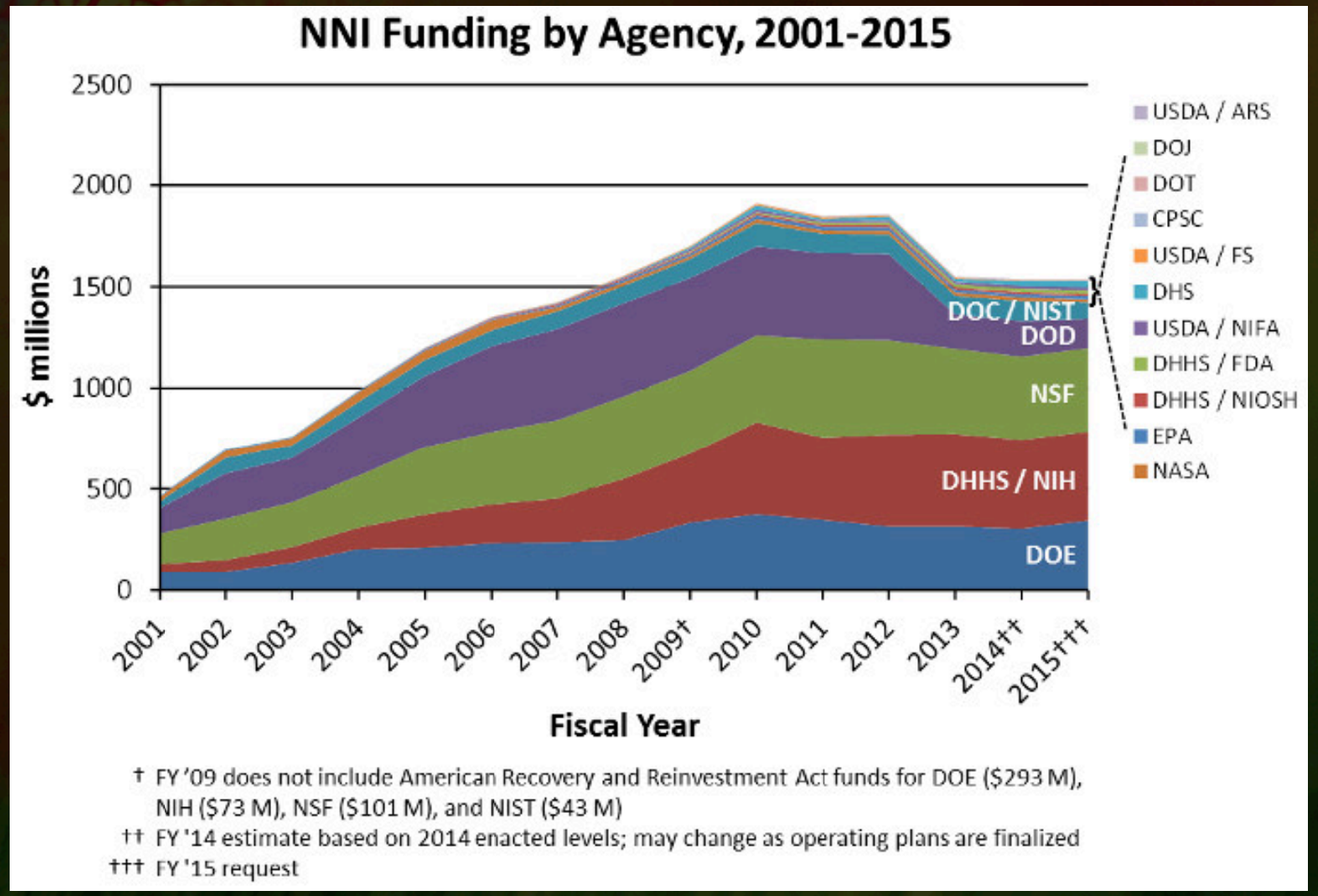
Image courtesy White House
http://www.whitehouse.gov/omb/memoranda_default

Excerpts

- “Federal agencies are encouraged to identify and pursue clearly defined "Grand Challenges"-ambitious … high-risk, high-return research.”
- “… President's Council of Advisors on Science and Technology discussed concerns about the reproducibility of scientific research. … Agencies should engage stakeholders to develop ways to improve the reproducibility of research … .”
- “Investments in STEM education should adhere to the priorities outlined in the Federal STEM Education 5-Year Strategic Plan.”

National Initiatives

- Example: National Nanotechnology Initiative (www.nano.gov)
- Started under President Clinton and continued under Presidents Bush and Obama



Source: National Nanotechnology Initiative Supplement to the President's 2015 Budget
http://www.nano.gov/sites/default/files/2015_nni_historical_agency_funding_chart2_small.jpg

Neuroscience and BRAIN Initiative

- President Obama announcement in April 2013
  - NIH, DARPA, and NSF
- Strong support from Rep Fatah

Image courtesy White House
Available at http://www.whitehouse.gov/blog/2013/04/02/brain-initiative-challenges-researchers-unlock-mysteries-human-mind

National Robotics Initiative (NRI) and Cyber-Physical Systems (CPS)

- NRI: NSF, NIH, USDA, and NASA
  - CISE, ENG, and others
- CPS
  - Interagency working group – NIST, NSF, DoD, DoT, NASA, …
- OSTP Assistant Director for Robotics and CPS - Richard Voyles

Press Release 13-179

National Robotics Initiative invests $38 million in next-generation robotics

NSF, NIH, USDA and NASA fund development of robots that collaborate with humans for enhanced productivity

Top image courtesy White House
Bottom image courtesy National Science Foundation

Key Policy Sectors

- Agriculture
- Cybersecurity
- Defense
- Education
- Energy and Environment
- Finance
- Healthcare
- Information and Communication Technology
- Trade
- Transportation and Infrastructure

Example: Synthetic Biology

- Briefing on the Hill on Synthetic Biology
- NSF supporting Woodrow Wilson Foundation and MIT to study ecological risk research agenda for Synthetic Biology (http://www.synbioproject.org/)

May 14, 2014

Synthetic Biology Still in Uncharted Waters of Public Opinion

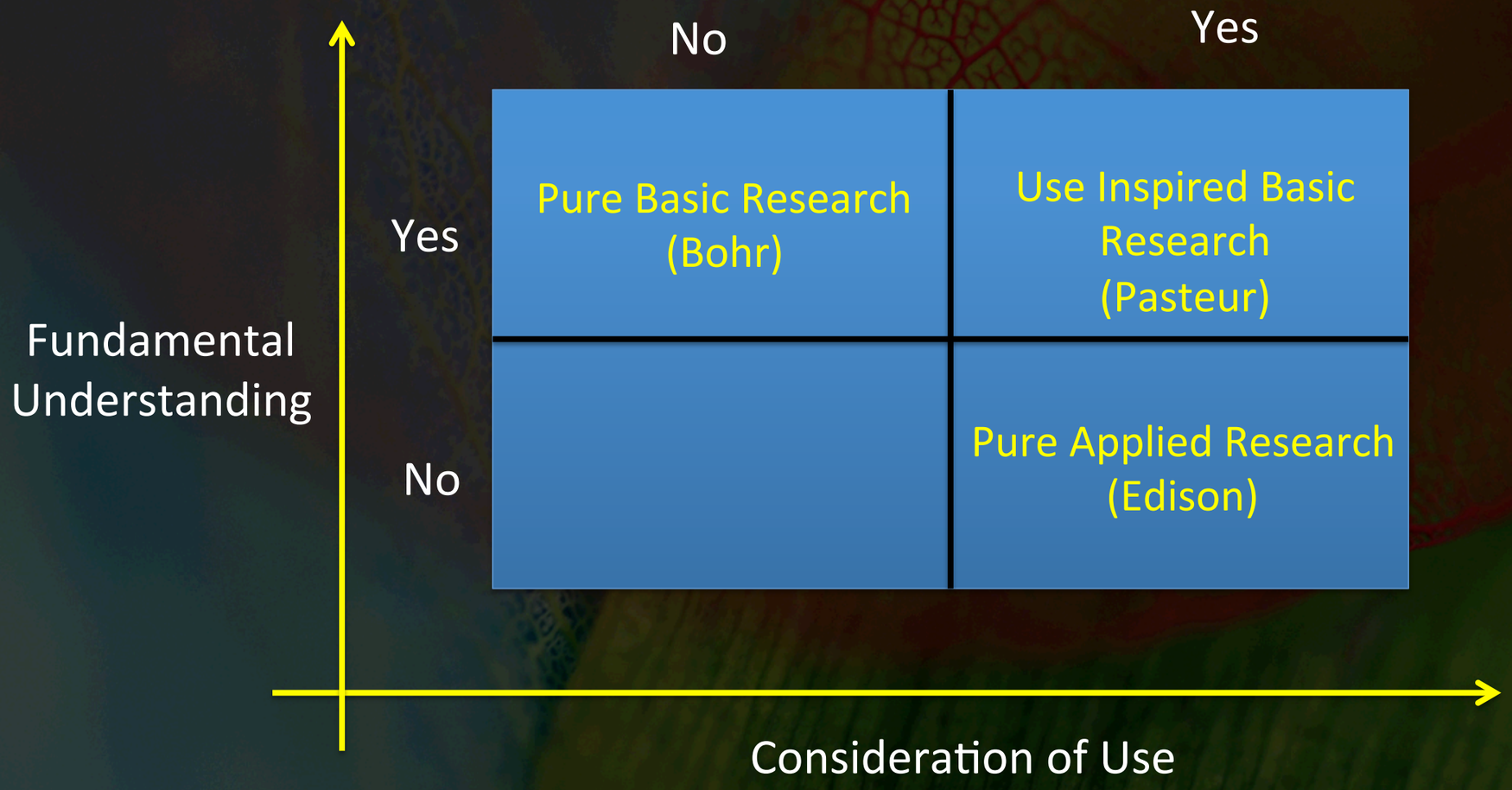
Image courtesy National Science Foundation
http://www.nsf.gov/news/news_summ.jsp?cntn_id=131810

“For emerging technologies that affect the global commons, concepts and applications should be published in advance of construction, testing, and release. This lead time enables public discussion of environmental and security concerns, research into areas of uncertainty, and development and testing of safety features. It allows adaptation of regulations and conventions in light of emerging information on benefits, risks, and policy gaps. Most important, lead time will allow for broadly inclusive and well-informed public discussion to determine if, when, and how gene drives should be used.”

Source: Regulating gene drive, Oye et al.
Available at http://www.sciencemag.org/content/early/recent / 17 July 2014 / Page 1 / 10.1126/science.1254287

Case for Science and Engineering Research Funding

Pasteur's Quadrant



Source: D. E. Stokes, Pasteur's Quadrant, 1997

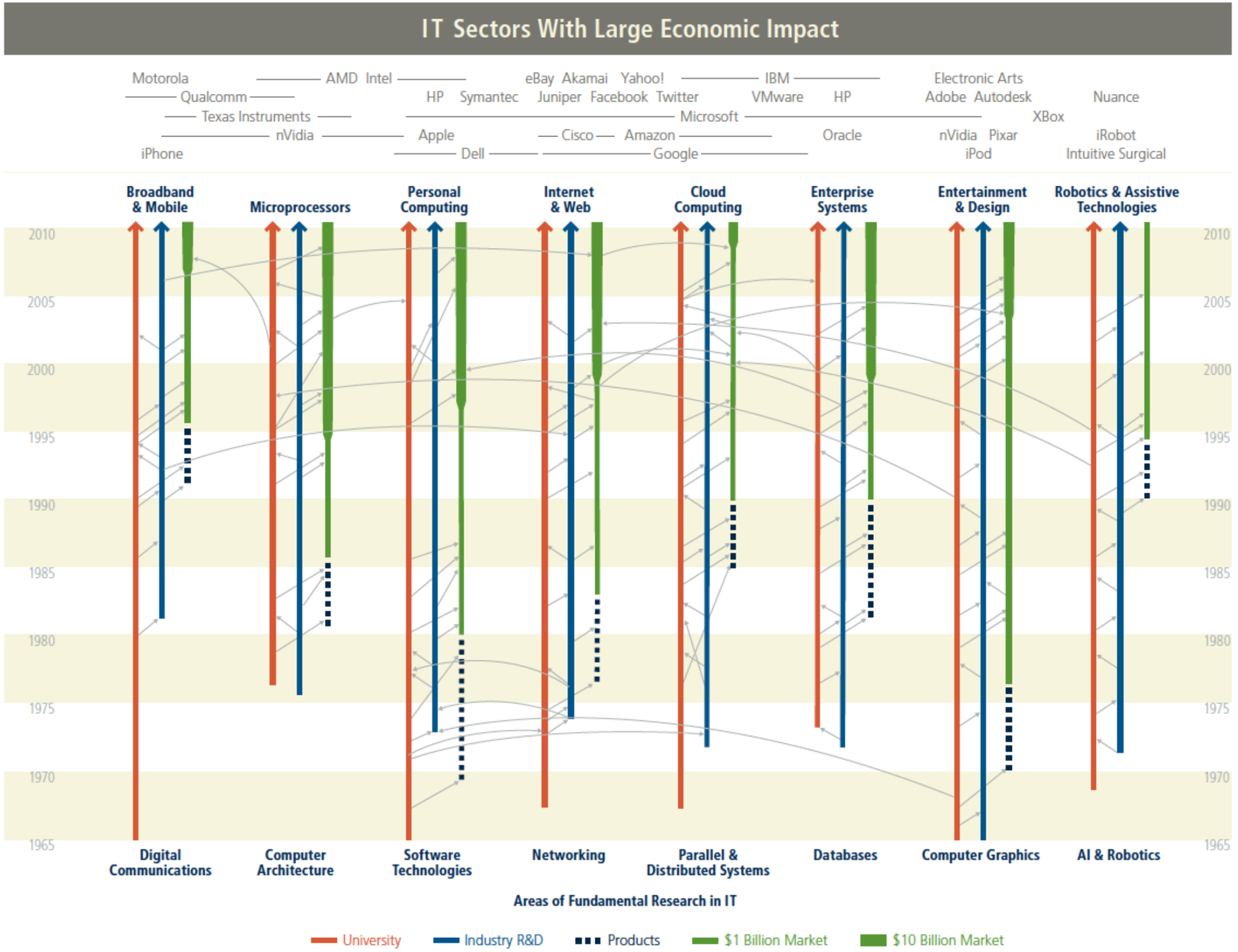


FIGURE 1 Examples of the contributions of federally supported fundamental research to the creation of IT sectors, firms, and products with large economic impact. Tracks added since the 2003 update of the figure are described in Appendix B. See also Box 1 and Appendix C.

Source: Continuing Innovation in Information Technology, 2012, NAP

iPhone – Federally Funded Technologies

- iPod, iPhone, iPad take advantage of federally-funded technologies
  - Lithium-ion batteries, signal compression, liquid-crystal display, Internet, HTTP/HTML, SIRI, and others
  - Funding from DARPA, CERN, DoD, DoE, NIH, NSF and other federal sources

Source: M. Mazzucato, Building the Entrepreneurial State
Available at http://marianamazzucato.com/projects/the-entrepreneurial-state/

Impact on Society

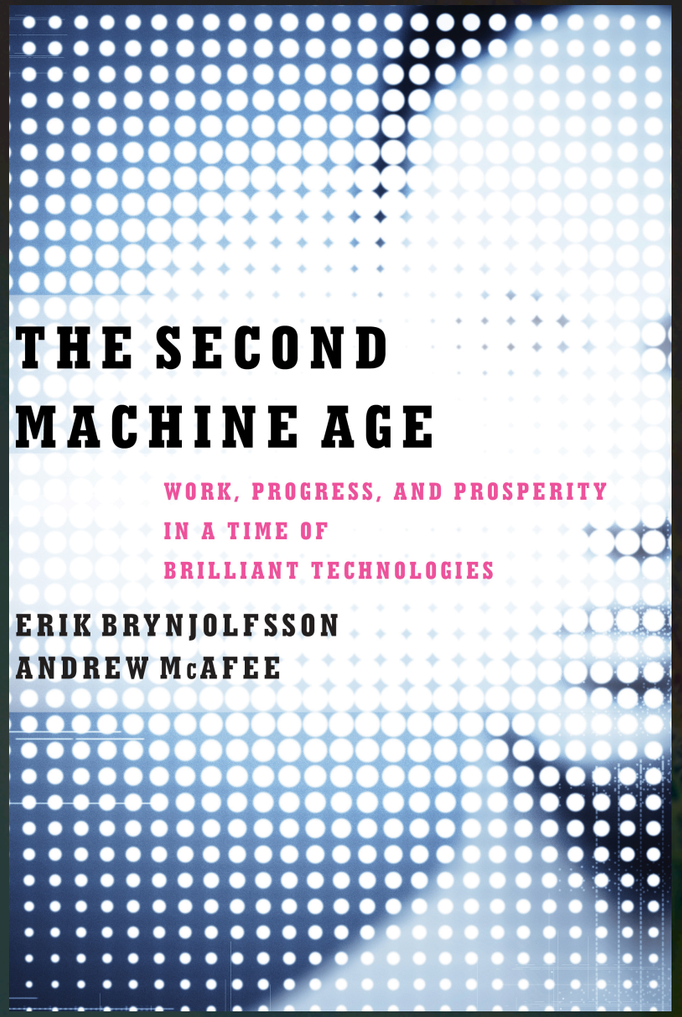


Image courtesy Erik Brynjolfsson and Andrew McAfee

THE FUTURE OF EMPLOYMENT: HOW SUSCEPTIBLE ARE JOBS TO COMPUTERISATION?,

Osborne and Frey, 2013, Oxford University

In this paper, we address the question: how susceptible are jobs to computerisation? … First, drawing upon recent advances in Machine Learning (ML) and Mobile Robotics (MR), we develop a novel methodology to categorise occupations according to their susceptibility to computerisation. Second, we … estimate the probability of computerisation for 702 detailed occupations, … impacts … on US labour market outcomes.

Public Understanding of Science and Technology

- Scientists assume that the benefits of scientific research are self evident
- Public does not, by and large, have a good understanding of science and technology
- Lack of understanding has serious long-term societal consequences
- It is imperative that scientists engage the public and policy makers on an ongoing basis

QUESTIONS?

IDEAS, THOUGHTS!

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