Opportunities in Engineering Research, Education and Innovation: A Perspective from NSF

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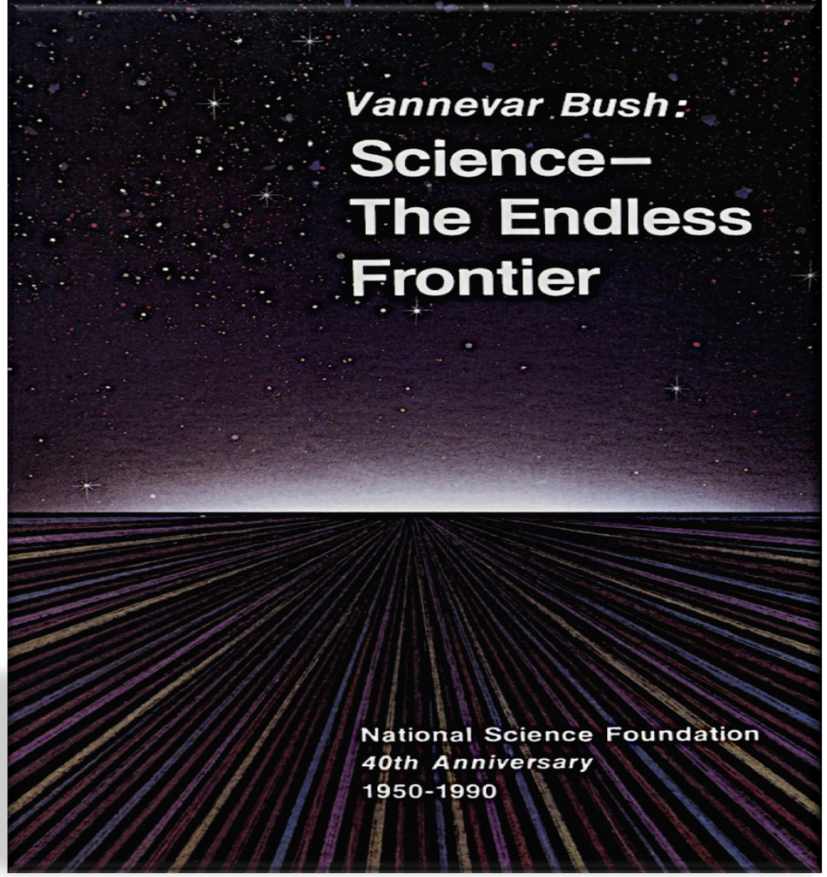
October 1, 2015

Outline

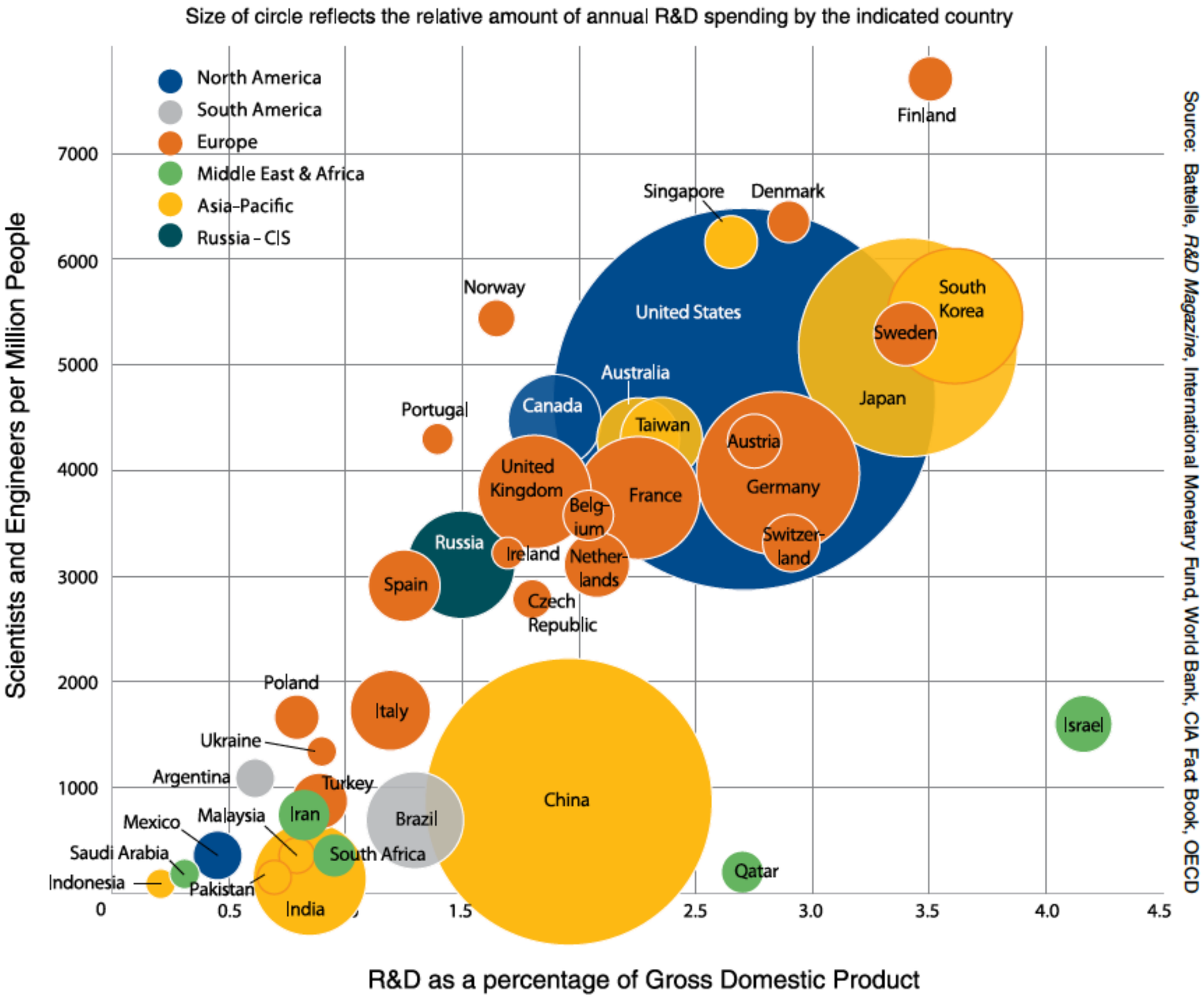
- Context, Drivers, and Trends
- NSF Engineering Budgets and Priorities
- Conclusions



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..

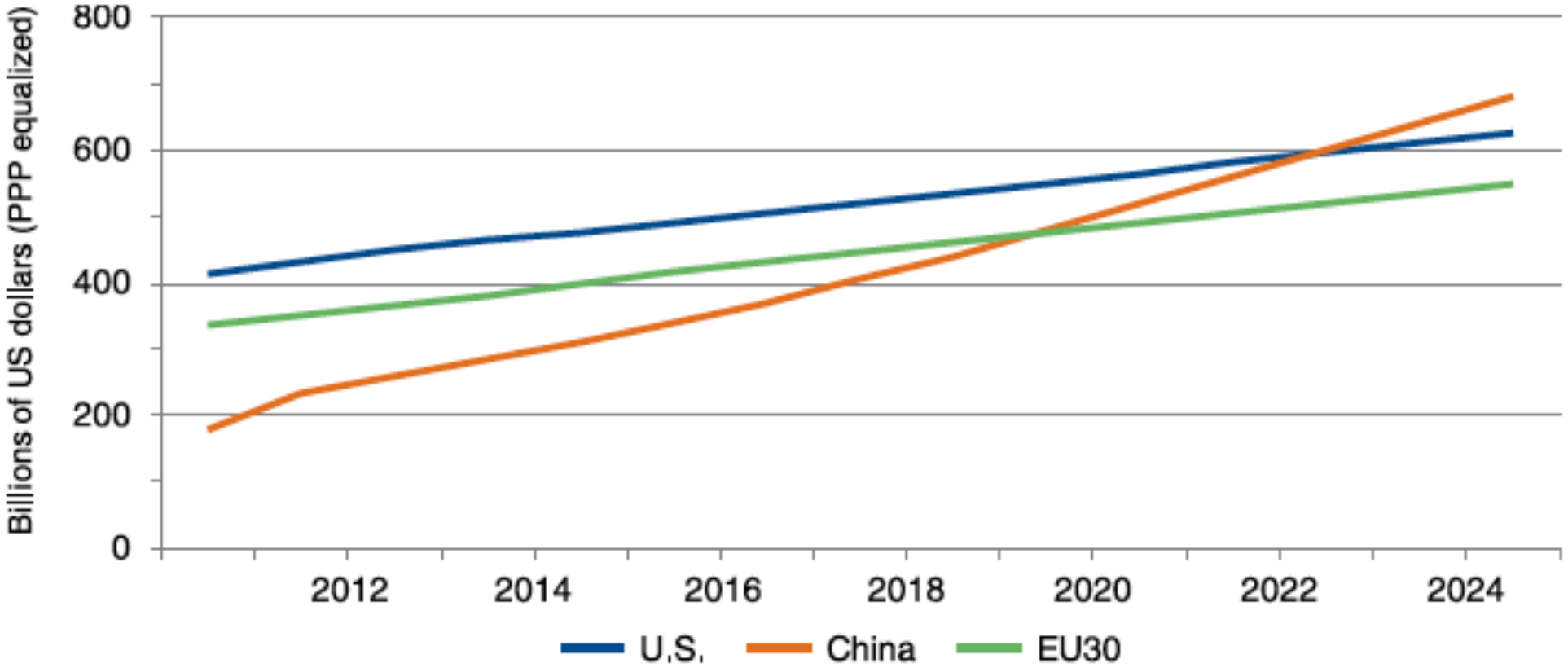
"to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…" NSF Act, 1950

Global R&D



Source: Battelle, *R&D Magazine*, International Monetary Fund, World Bank, CIA Fact Book, OECD

Global R&D Forecast

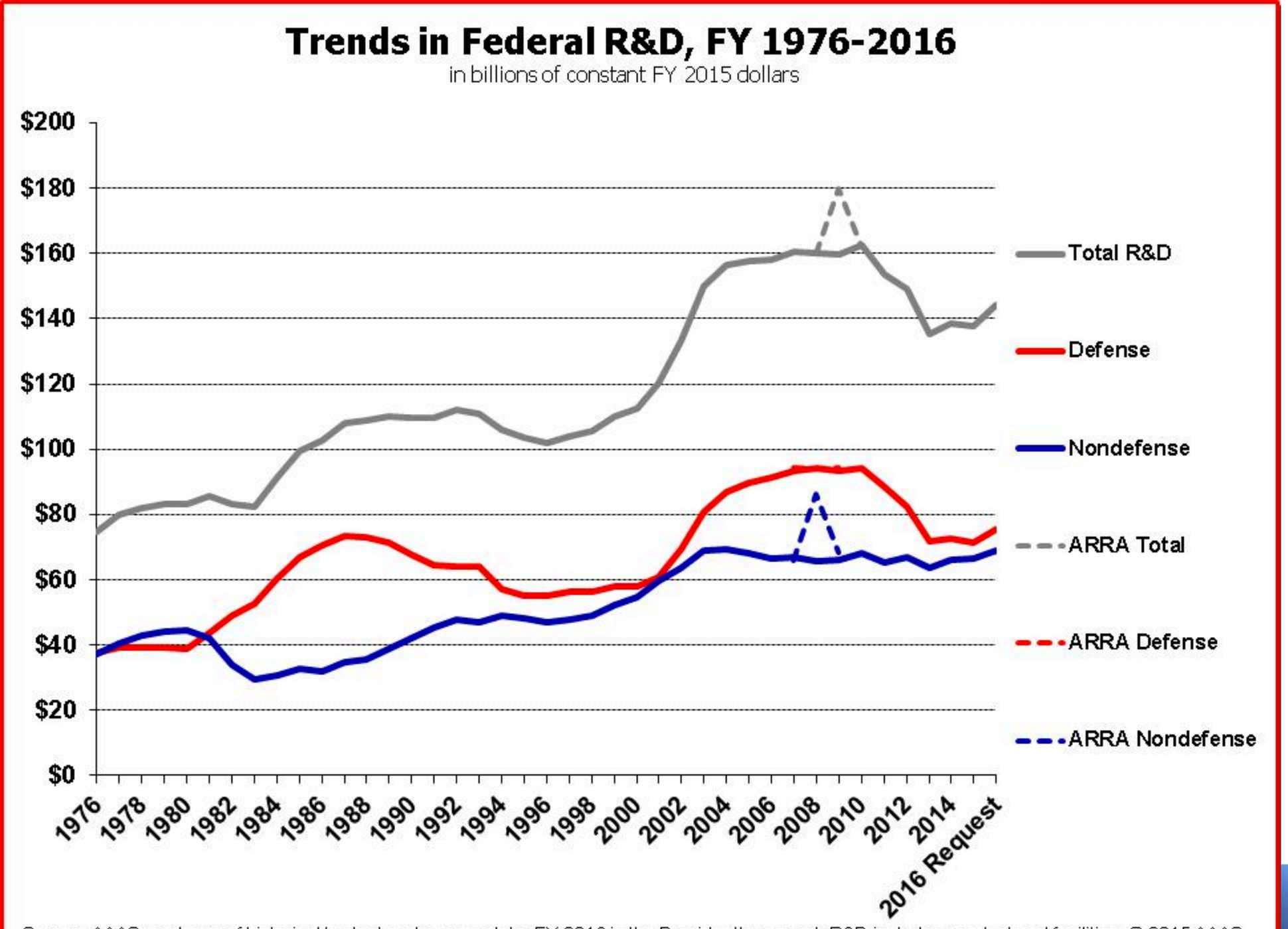


Long-Term Outlook for R&D Expenditures

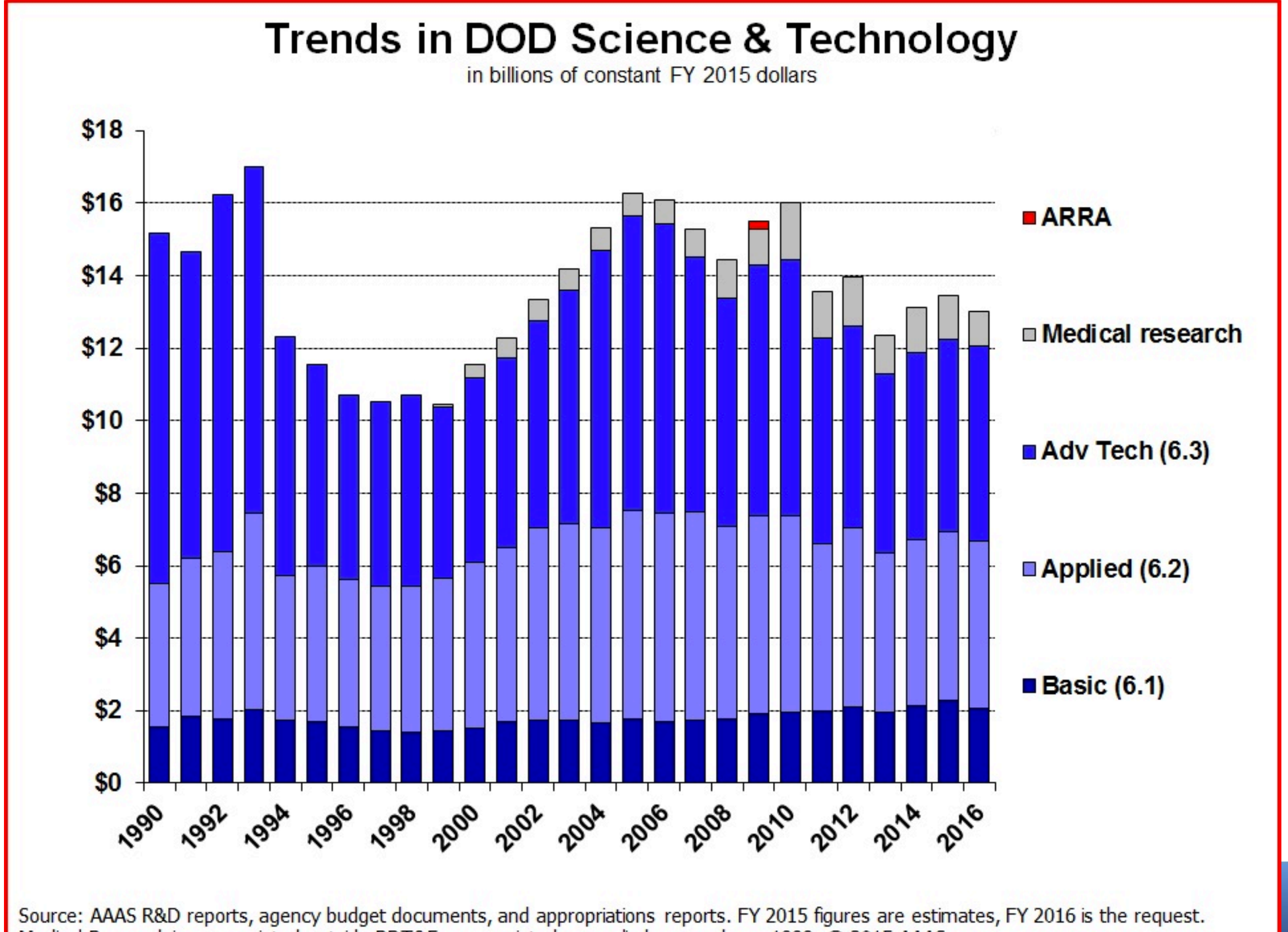
Even if the historic stability of the U.S. and European commitment to research intensity (i.e., spending as a percent of GDP) continues, growth in China's economy is likely to propel it to the top position in absolute R&D spending by the early 2020s.

Source: Battelle and *R&D Magazine*

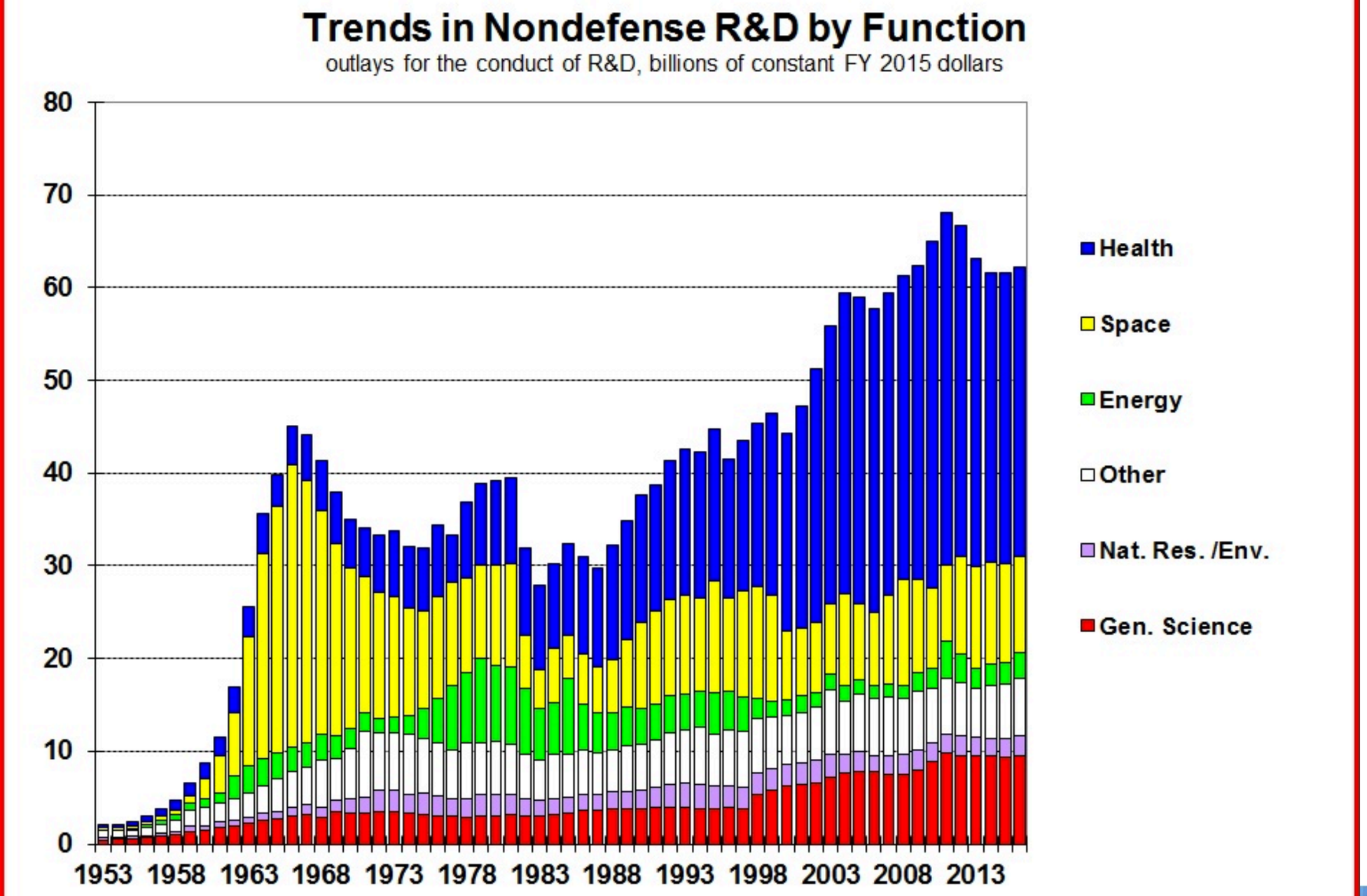
Federal R&D


Trends in Federal R&D, FY 1976-2016
in billions of constant FY 2015 dollars
$200
$180
$160
$140
$120
$100
$80
$60
$40
$20
$0
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016 Request
Total R&D
Defense
Nondefense
ARRA Total
ARRA Defense
ARRA Nondefense
Source: AAAS analyses of historical budget and agency data. FY 2016 is the President's request. R&D includes conduct and facilities. © 2015 AAAS

Defense R&D

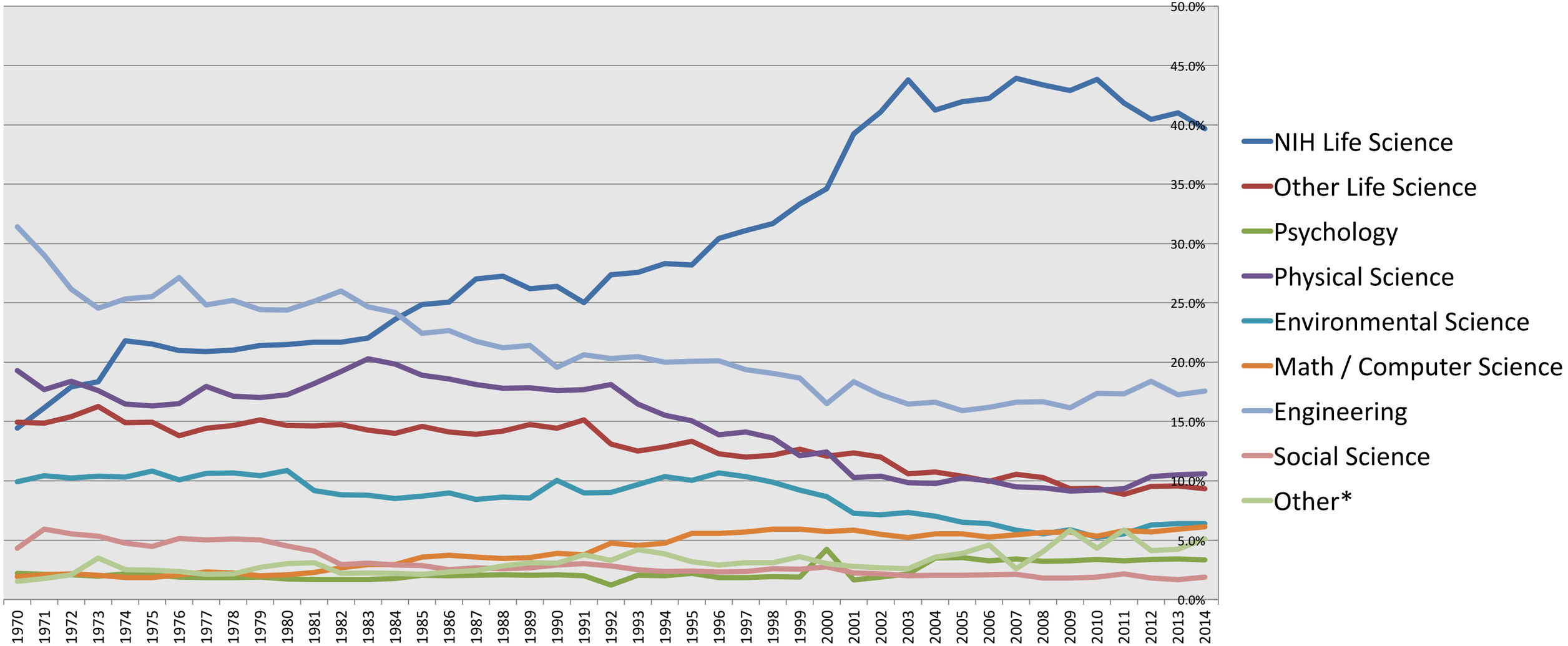

Trends in DOD Science & Technology
in billions of constant FY 2015 dollars
$18
$16
$14
$12
$10
$8
$6
$4
$2
$0
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
ARRA
Medical research
Adv Tech (6.3)
Applied (6.2)
Basic (6.1)
Source: AAAS R&D reports, agency budget documents, and appropriations reports. FY 2015 figures are estimates, FY 2016 is the request.
Medical Research is appropriated outside RDT&E; appropriated as applied research pre-1999. © 2015 AAAS

Nondefense R&D



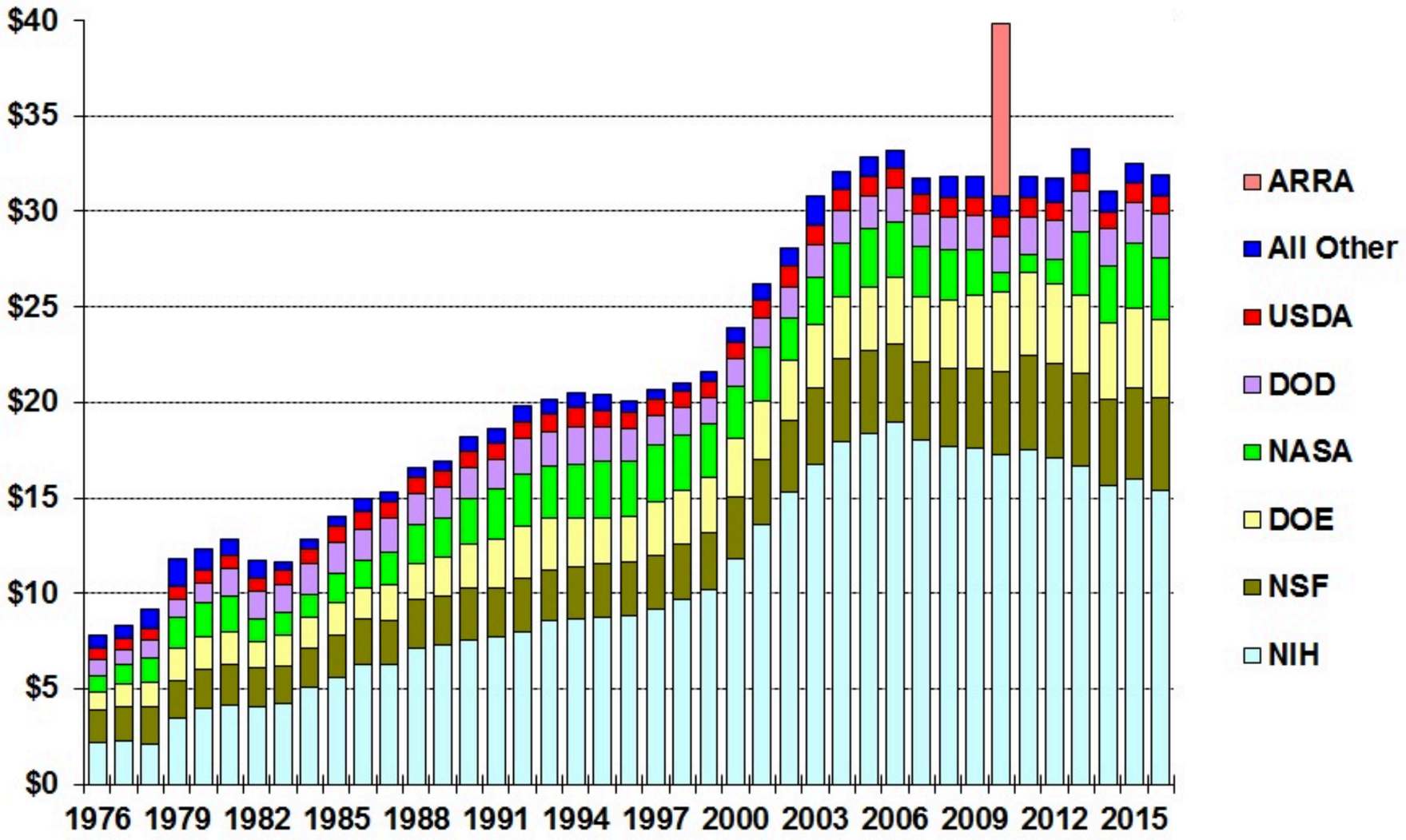
Source: AAAS, based on OMB Historical Tables in *Budget of the United States Government FY 2016*. Some Energy programs shifted to General Science beginning in FY 1998. © 2015 AAAS

Trend across Scientific Fields



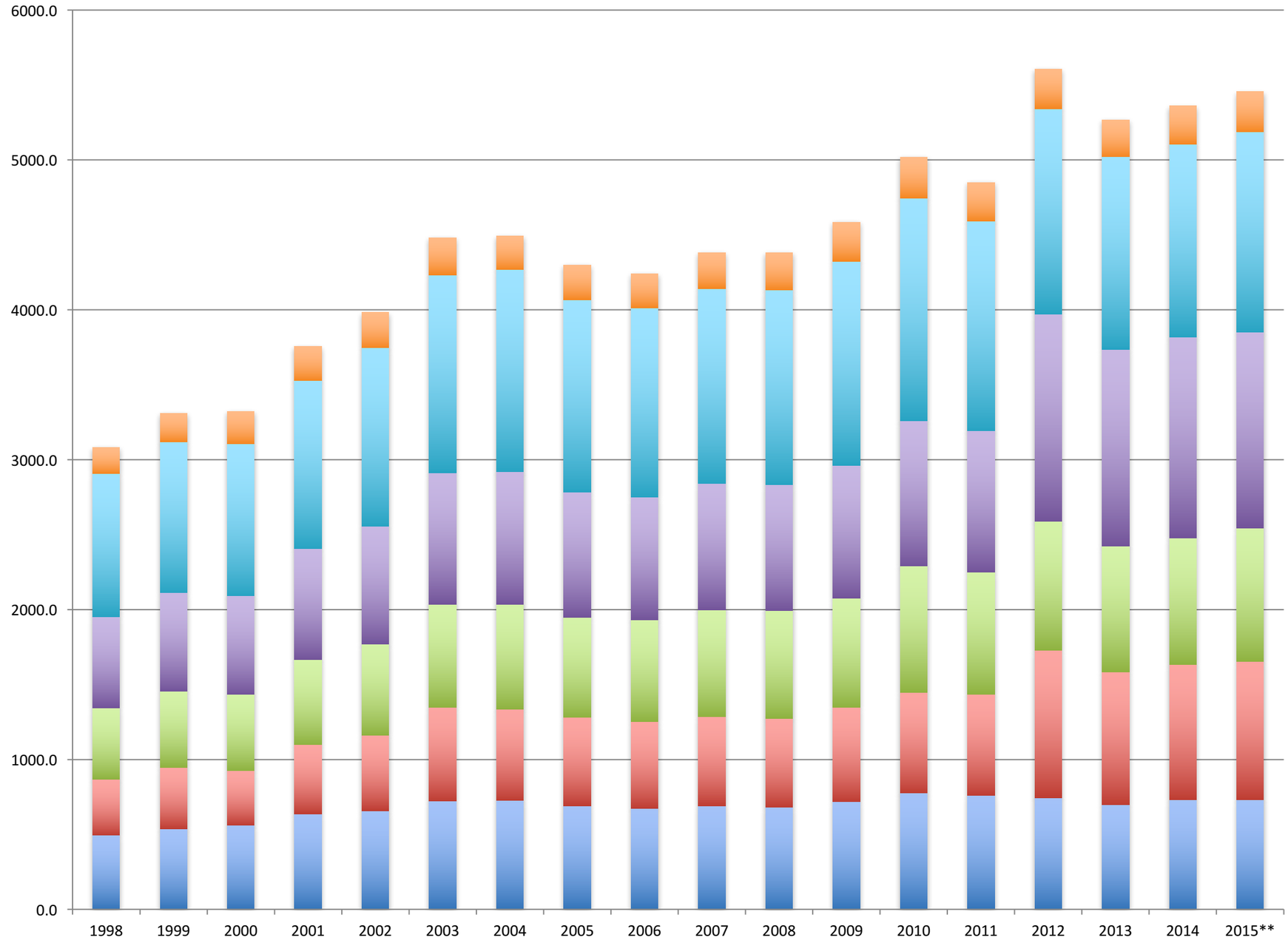
Basic and applied research only

Basic Research



Source: *AAAS Report: Research & Development* series. FY 2015 figures are latest estimates, FY 2016 is the President's request.

NSF Budgets



- Social, Behavioral and Economic Sciences
- Mathematical and Physical Sciences
- Geosciences*
- Engineering
- Computer and Information Science and Engineering*
- Biological Science

NSF Budget 2016

Table 1: National Science Foundation R&D and Total Budget
(budget authority in millions of dollars)

	FY 2014 Actual	FY 2015 Estimate	**FY 2016 Budget**	Change FY 15-16 Amount	Change FY 15-16 Percent
Total NSF R&D	5,800	5,999	**6,309**	310	5.2%
NSF R&D by Character					
Conduct of R&D	5,403	5,562	**5,864**	302	5.4%
R&D Facilities	397	437	**445**	8	1.9%
Total NSF Budget	7,131	7,344	**7,724**	379	5.2%
Biological Sciences	721	731	**748**	17	2.3%
Comp and Info Sci and Eng	893	922	**954**	33	3.5%
Engineering	833	892	**949**	57	6.4%
Geosciences	1,321	1,304	**1,365**	61	4.7%
Math and Physical Sci	1,268	1,337	**1,366**	30	2.2%
Social, Behav and Econ Sci	257	272	**291**	19	7.1%

Source: OMB R&D data, agency budget justification and Quantitative Data Tables.

All figures rounded to the nearest million. Changes calculated from unrounded figures.

Case for Science and Engineering Research

- Science and engineering advances are important drivers of economy, health, security, quality of life, and sustainability
- Fundamental research requires public sector support
- NSF has a unique role among Federal agencies in supporting long-term fundamental research

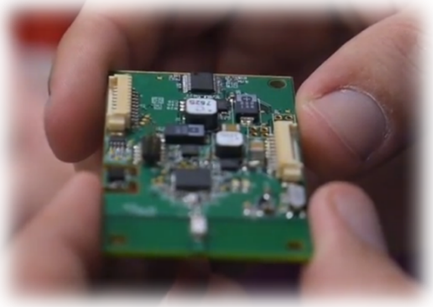
Important to connect research discoveries and inventions to real-world deployment

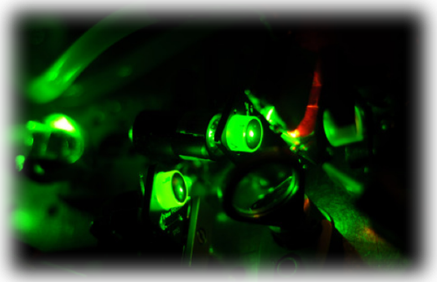
NSF Foundation-wide Priorities

- Innovations at the Nexus of Food, Water and Energy Systems (INFEWS)
- Risk and Resilience
- Understanding the Brain (UtB)
- Inclusion across the Nation of Communities of Learners that have been Underrepresented for Diversity in Engineering and Science (NSF INCLUDES)
- Clean Energy
- Cyber-enabled Materials, Manufacturing and Smart Systems (CEMMSS)
- Cyber-infrastructure for 21st Century Science, Engineering, and Education (CIF21)
- Secure and Trustworthy Cyberspace
- Research at the Interface of Biology, Mathematical and Physical (BioMAPS)
- NSF Innovation Corps

NSF Engineering Directorate (ENG)

Investing in engineering research and education and fostering innovations to benefit society





Credits, left to right: Google; Shanti Hamburg, MAE, West Virginia University; NSF; NSF; Franz X. Kärtner and Greg Hren, MIT.

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 (AI)
  - New platforms for computing
- 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
  - Understanding and new tools at the atomic and molecular scales
  - Wide range of applications – biomed, energy, water, materials, electronics
  - From passive components to active systems, design, and manufacturing
- Biological/Medical Frontier
  - 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/social 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, …*

Directorate for Engineering

Fundamental

EFRI

CBET

- Chemical, Biochemical, and Biotechnology Systems
- Biomedical Engineering and Engineering Healthcare
- Environmental Engineering and Sustainability
- Transport and Thermal Fluids Phenomena

CMMI

- Advanced Manufacturing
- Mechanics and Engineering Materials
- Resilient and Sustainable Infrastructure
- Systems Engineering and Design

ECCS

- Electronics, Photonics, and Magnetic Devices
- Communications, Circuits, and Sensing Systems
- Energy, Power, and Adaptive Systems

EEC

- Engineering Research Centers
- Engineering Education
- Engineering Workforce

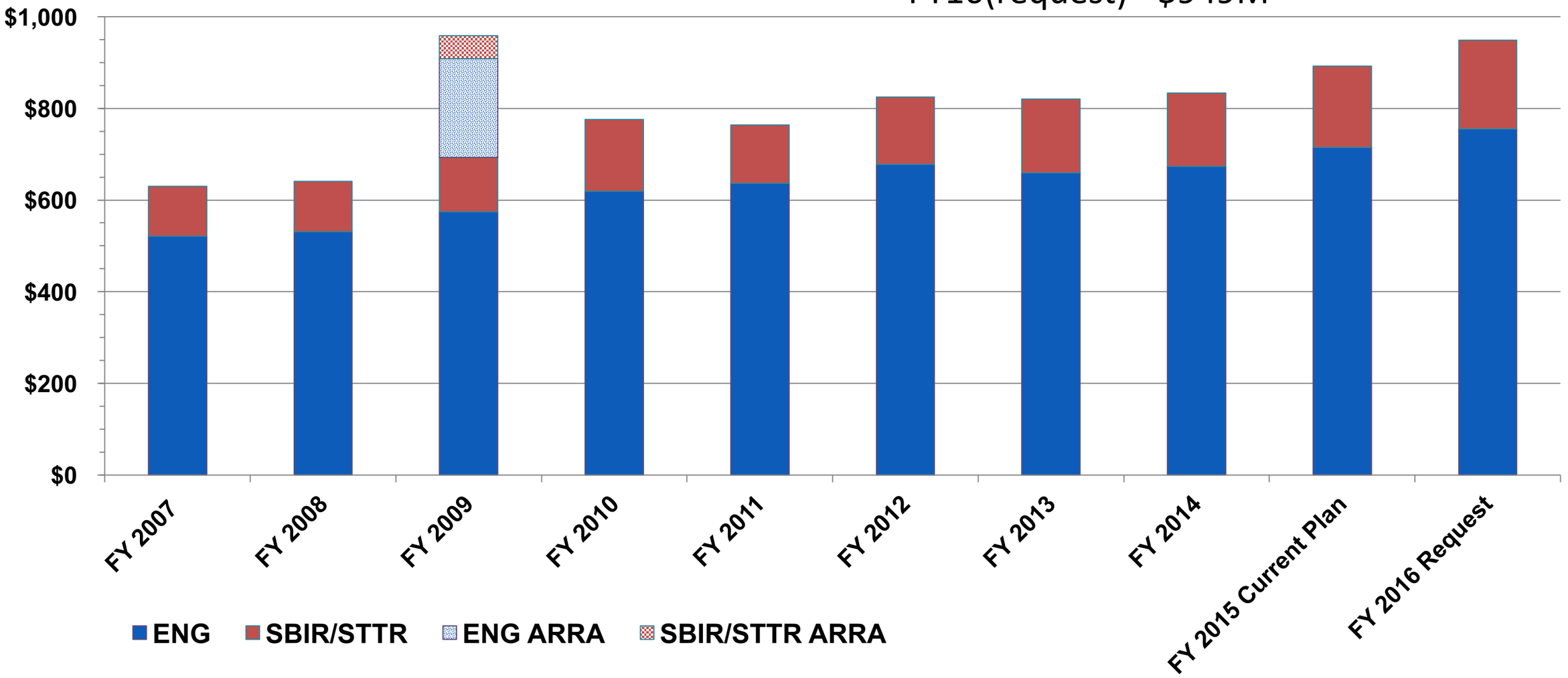
Translational

IIP

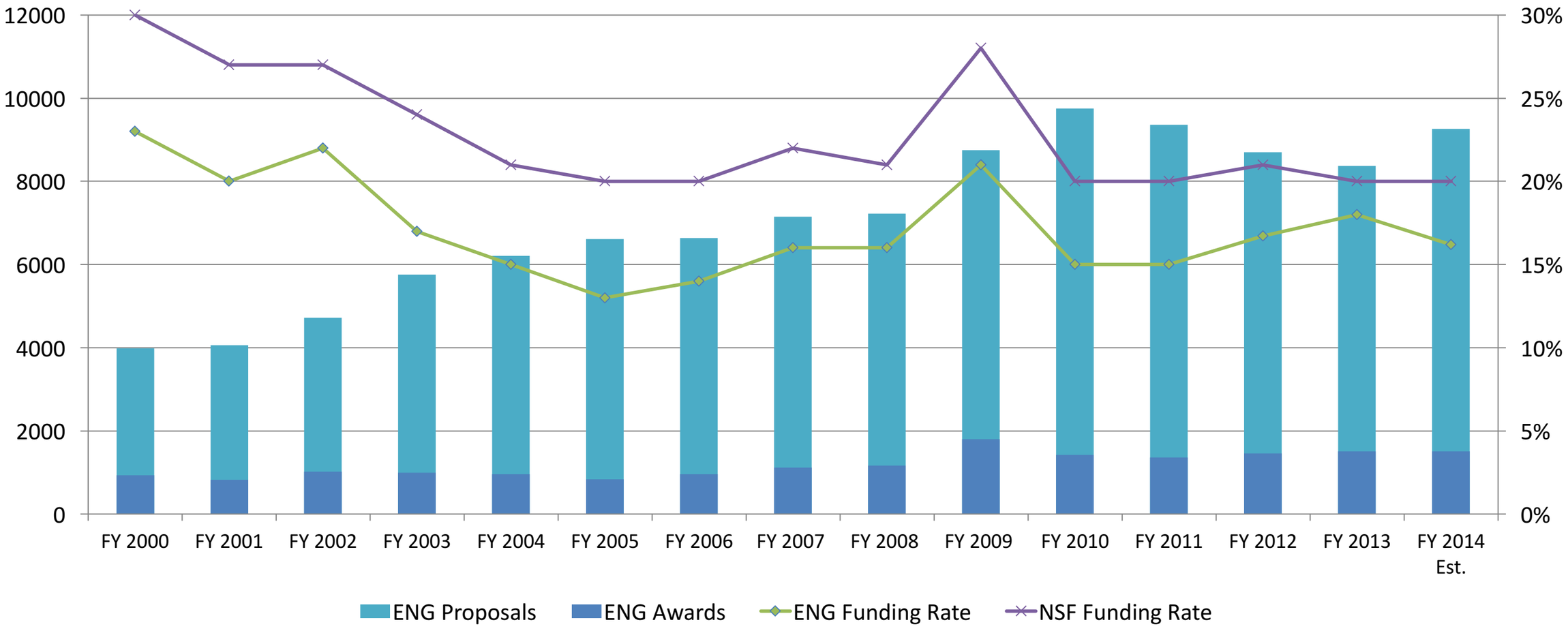
- Academic Partnerships
- Small Business Partnerships

ENG Budget ($M)

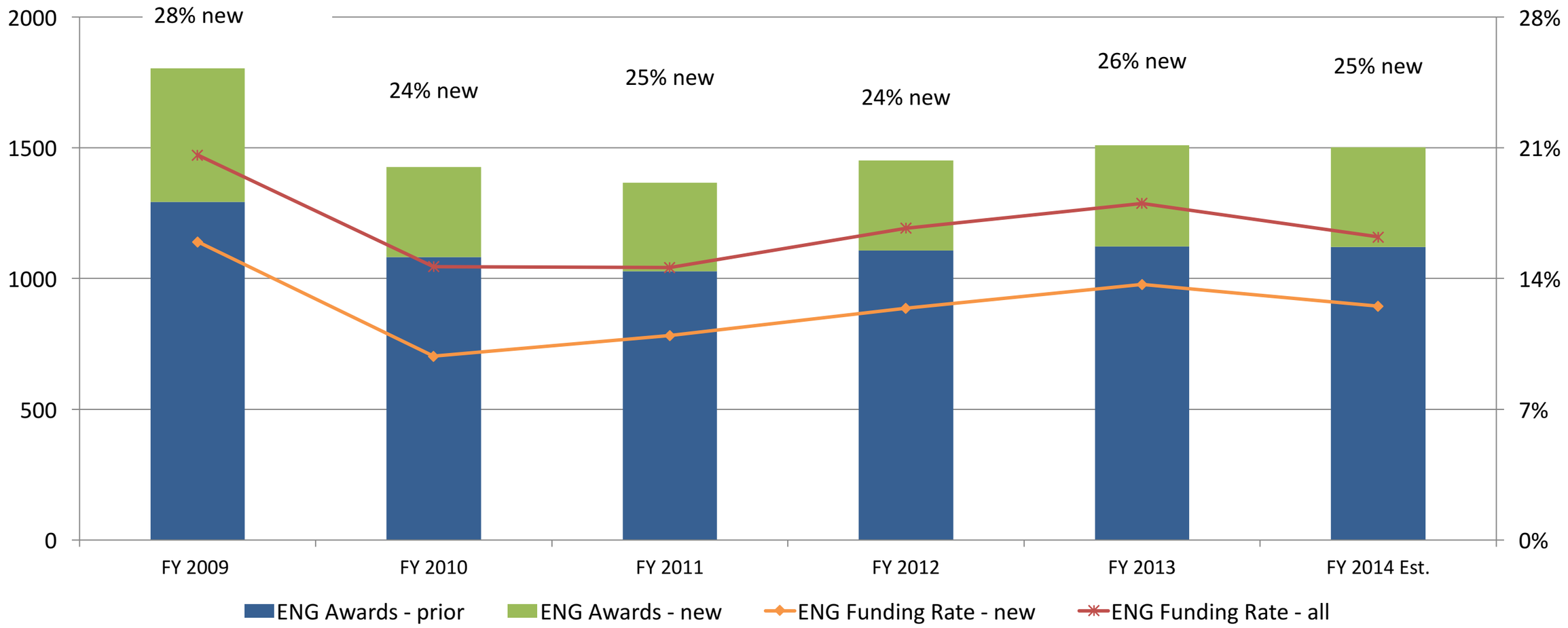
FY14 - $833M
FY15 - $892M
FY16(request) - $949M



ENG Research Proposals and Awards



ENG Research Awards to New and Prior NSF Researchers



ENG Initiatives and Priorities Address National Interests

- **Innovations at the Nexus of Food, Energy, and Water Systems**
- **Risk and Resilience – Resilient Infrastructure Systems**
  - Urban Science – Smart and Connected Communities
- Clean Energy Technology
- Cyber-Enabled Materials, Manufacturing, and Smart Systems
  - Advanced Manufacturing
- National Nanotechnology Initiative
- Communications and Cyberinfrastructure
- Optics and Photonics
- **Understanding the Brain**
- Education and Broadening Participation
  - **Inclusion across the Nation of Communities of Learners that have been Underrepresented for Diversity in Engineering and Science (NSF INCLUDES)**
  - **IUSE:RED – Improving Undergraduate Science and Engineering: Revolutionizing Engineering Departments**
- Innovation Corps

Concluding Comments

- Intense competition among universities
- NSF committed to supporting long-term fundamental research
- Public understanding of importance of science and engineering research

QUESTIONS?

IDEAS, SUGGESTIONS!

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