REPORT TO THE PRESIDENT

TRANSFORMATION AND OPPORTUNITY: THE FUTURE OF THE U.S. RESEARCH ENTERPRISE

Executive Office of the President

President's Council of Advisors on Science and Technology

NOVEMBER 2012

REPORT TO THE PRESIDENT

TRANSFORMATION AND OPPORTUNITY: THE FUTURE OF THE U.S. RESEARCH ENTERPRISE

Executive Office of the President

President’s Council of Advisors on Science and Technology

NOVEMBER 2012

The President's Council of Advisors on Science and Technology

Co-Chairs

John P. Holdren
Assistant to the President for Science and Technology
Director, Office of Science and Technology Policy

Eric Lander
President
Broad Institute of Harvard and MIT

Vice Chairs

William Press
Raymer Professor in Computer Science and Integrative Biology
University of Texas at Austin

Maxine Savitz
Vice President
National Academy of Engineering

Members

Rosina Bierbaum
Professor of Natural Resources and Environmental Policy
School of Natural Resources and Environment and School of Public Health
University of Michigan

Christine Cassel
President and CEO
American Board of Internal Medicine

Christopher Chyba
Professor, Astrophysical Sciences and International Affairs
Director, Program on Science and Global Security
Princeton University

S. James Gates, Jr.
John S. Toll Professor of Physics
Director, Center for String and Particle Theory
University of Maryland, College Park

Mark Gorenberg
Managing Director
Hummer Winblad Venture Partners

Shirley Ann Jackson
President
Rensselaer Polytechnic Institute

Richard C. Levin
President
Yale University

Chad Mirkin
Rathmann Professor, Chemistry, Materials Science and Engineering, Chemical and Biological Engineering and Medicine
Director, International Institute for Nanotechnology
Northwestern University

Mario Molina
Professor, Chemistry and Biochemistry
University of California, San Diego
Professor, Center for Atmospheric Sciences at the Scripps Institution of Oceanography
Director, Mario Molina Center for Energy and Environment, Mexico City

Ernest J. Moniz
Cecil and Ida Green Professor of Physics and Engineering Systems
Director, MIT's Energy Initiative
Massachusetts Institute of Technology

Craig Mundie
Chief Research and Strategy Officer
Microsoft Corporation

Ed Penhoet
Director, Alta Partners
Professor Emeritus, Biochemistry and Public Health
University of California, Berkeley

Barbara Schaal
Mary-Dell Chilton Distinguished Professor of Biology
Washington University, St. Louis
Vice President, National Academy of Sciences

Eric Schmidt
Chief Executive
Google, Inc.

Daniel Schrag
Sturgis Hooper Professor of Geology
Professor, Environmental Science and Engineering
Director, Harvard University Center for Environment
Harvard University

David E. Shaw
Chief Scientist, D.E. Shaw Research
Senior Research Fellow, Center for Computational Biology and Bioinformatics
Columbia University

Ahmed Zewail
Linus Pauling Professor of Chemistry and Physics
Director, Physical Biology Center
California Institute of Technology

Staff[1]

Deborah Stine
Executive Director

Amber Hartman Scholz
Assistant Executive Director

[1] Danielle Evers staffed this report prior to her departure in June 2012. Please see page 102.

1.7 Summary of Key Opportunities and Supporting Sets of Actions

PCASTs "Transformation and Opportunity" Key Opportunities and Supporting Sets of Actions	
Key Opportunities	**Supporting Sets of Actions (details in Main Text)**
#1. The Nation has the opportunity to maintain its world-leading position in research investment, structured as a mutually supporting partnership among industry, the Federal Government, universities, and other governmental and private entities.	#1.1. Reaffirm the President's goal that total R&D expenditures should achieve and sustain a level of 3 percent of GDP. Congressional authorization committees should take ownership of pieces of that goal, with the Executive Branch and Congress establishing policies to enhance private industry's major share. (Section 4.1) #1.2. Recognizing the inherent political difficulty, we nevertheless urge Congress and the Executive Branch to find one or more mechanisms for increasing the stability and predictability of Federal research funding, including funding for research infrastructure and facilities. Possibilities include a cross-agency, multiyear program and financial plan akin to DoD's Future Years Defense Program (FYDP) or closer coupling of multiyear authorizations to actual appropriations for R&D. (Section 4.1) #1.3. The R&D tax credit needs to be made permanent. An increase in the rate of the alternative simplified credit from 14 percent to 20 percent would not be excessive. The credit also needs to be made more useful to small and medium enterprises that are R&D intensive by instituting any or all of (1) refundable tax credits, (2) transferable tax credits, or (3) modifications in the definition of net operating loss to give advantage to R&D expenditures. (Section 4.2) #1.4. Adopt policies that increase the productivity of researchers, including more people-based awards, larger and longer awards for some merit-selected investigators, and administratively efficient grant mechanisms. (Section 4.3)
#2. The Federal Government has the opportunity to enhance its role as the enduring foundational investor in basic and early applied research in the United States. It can adopt policies that are most consistent with that role. Federal policy can seek to foster a sustainable R&D enterprise in which, when research is deemed worth supporting, it is supported for success.	#2.1. Identify and achieve regulatory policy reforms, particularly relating to the regulatory burdens on research universities. (Section 4.4) • The Association of American Universities-Association of Public and Land-grant Universities-Council on Governmental Relations (AAU-APLU-COGR) consensus list deserves attention #2.2. Appropriately circumscribe the use of cost sharing by funding agencies. (Section 4.4) • Apply 2009 NSF reforms Federal Government-wide
#3. Federal agencies have the opportunity to grow portfolios that more strategically support a mix of evolutionary vs. revolutionary research; disciplinary vs. interdisciplinary work; and project-based vs. people-based awards.	#3.1. Each agency should have a strategic plan that explicitly addresses the different kinds of research activities that can contribute to its mission, specifically addressing the axes of evolutionary vs. revolutionary research; disciplinary vs. interdisciplinary work; and project-based vs. people-based awards. (Section 4.5) #3.2. Each agency should diversify its mechanisms for merit review so as to be optimal for the portfolio in its strategic plan. (Section 4.5)

<table>
<tr><td></td><td>#3.3. Each agency should adopt policies that increase the agility of funding new fields, unexpected opportunities, and the creativity of new researchers. (Section 4.5)
• Fellowships (including portable) and training grants
• Early career opportunities</td></tr>
<tr><td>#4. There is the opportunity for government to create additional policy encouragements and incentives for industry to invest in research, both on its own and in new partnerships with universities and the National Laboratories.</td><td>#4.1. Improve STEM education so as to produce more and better home-grown researchers and technology entrepreneurs. (Section 5.1)
• Two previous PCAST reports recommend policy directions

#4.2. Attract and retain, both for universities and industry, the world's best researchers and students from abroad. (Section 5.1)
• Visa reform for high-ability STEM graduates

#4.3. Support the President's Export Control Reform initiative and further measures. (Section 5.2)
• Reduce "deemed export" burdens on universities
• Unleash U.S. firms to compete internationally

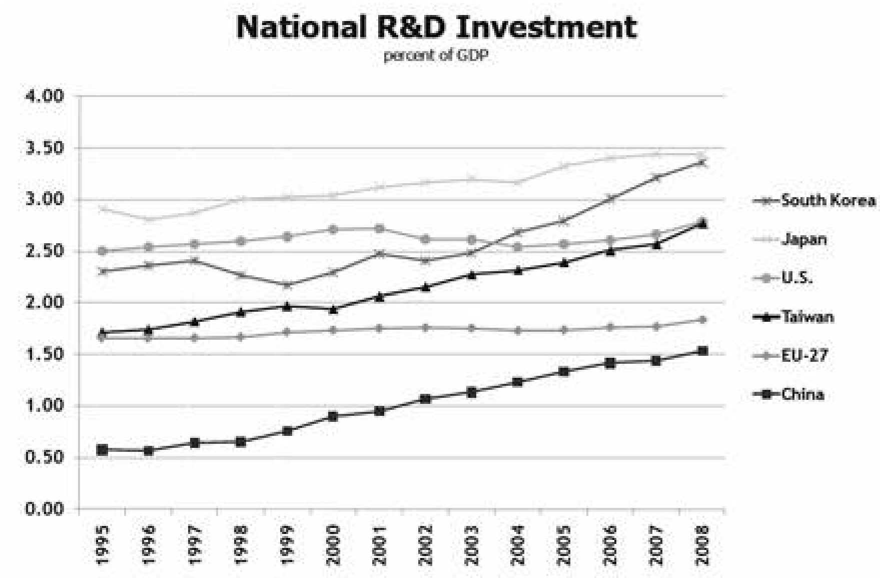
#4.4. Enable streamlined interactions between U.S. National Laboratories and industry. (Section 5.3)</td></tr>
<tr><td>#5. Research universities have the opportunity to strengthen and enhance their additional role as hubs of the innovation ecosystem. While maintaining the intellectual depth of their foundations in basic research, they can change their educational programs to better prepare their graduates to work in today's world. They can become more proactive in transferring research results into the private sector.</td><td>#5.1. Maintain strong commitment to the scope and intellectual depth of fundamental university research. (Section 6.1)
• Fundamental research provides the foundation for future world-changing new industries

#5.2. Augment the educational mission for today's world. (Section 6.2)
• Train for entrepreneurship and technology transfer
• Prepare for national needs and grand challenges
• Increase undergraduate research experiences

#5.3. Embrace more fully the additional role of universities as hubs of the innovation ecosystem. (Section 6.3)
• Technology licensing best practices
• Proof-of-concept centers
• Leadership in public-private partnerships

#5.4. Confront difficult career-development and workforce issues, including length of time to Ph.D. and the reliance of the S&T enterprise on the labor of early career training positions. (Section 6.4)</td></tr>
</table>

Figure 3-1. National R&D Investment



Source: Patrick J. Clemens, "Historical Trends in Federal R&D," AAAS. Data source: OECD, Main Science and Technology Indicators, February 2011.

Although total U.S. R&D is still greater than that of any other single country, from 1999 to 2009, the U.S. share of the world's R&D investment shrank from 38 percent to 31 percent.[51] China is now the world's second-largest R&D performer. In 2008, its universities produced more Ph.D.'s (49,698 across all fields) than the United States.[52] Countries in Asia collectively performed 32 percent of world R&D in 2009, edging out the U.S. total.[53] Singapore's government drives its flagship research universities (The National University of Singapore, Nanyang Technological University, and Singapore Management University[54]) to assess their quality against international peers, with considerable and continuing success.[55] More published scientific papers come from the European Union (about 250,000 in 2007) than from the United States.[56] While the United States still retains leadership in most areas of research and development investment and success, these are trends of enormous significance. As we will see in the next two sections, they drive the need to strengthen and expand relationships between U.S. industry and Ameri-

[51] Battelle and R&D Magazine, "2012 Global R&D Funding Forecast," 2011, at battelle.org/docs/default-document-library/2012_global_forecast.pdf

[52] National Research Council, "Research Universities and the Future of America," 2012, at download.nap.edu/catalog.php?record_id=13299

[53] National Science Board, *Science and Engineering Indicators 2012*.

[54] National University of Singapore, Nanyang Technological University, and Singapore Management University.

[55] Singapore Government, Ministry of Education, International Academic Advisory Panel, Press Release, November 12, 2010, www.moe.gov.sg/media/press/2010/11/advisory-panel-endorses-continuing-investments-in-higher-education.php

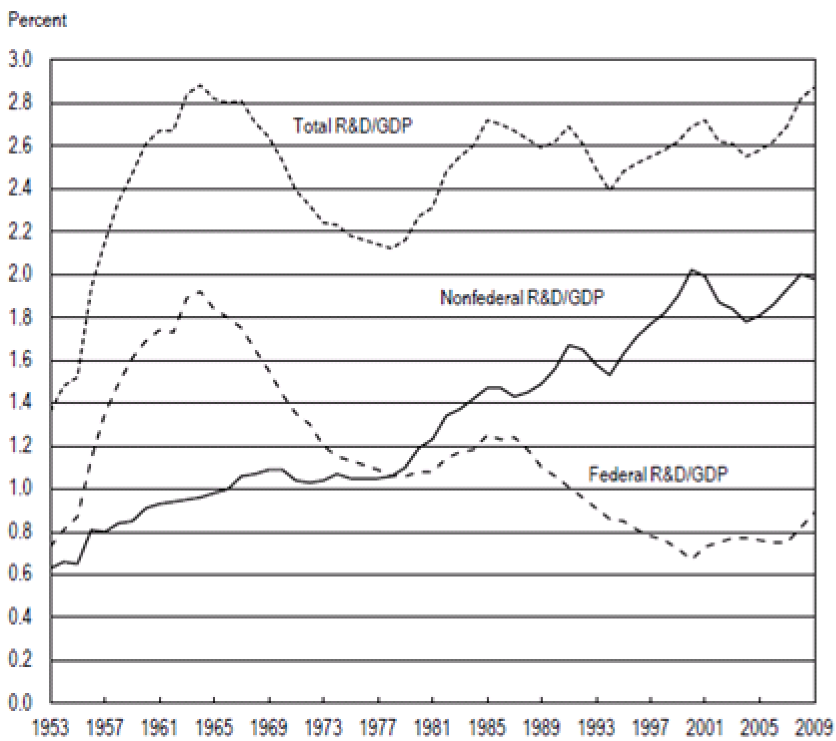
[56] National Science Board, *Science and Engineering Indicators 2010* (Arlington VA: National Science Foundation, NSB 10-01).

can universities and National Laboratories.

3.2 Research in Industry Has Shifted Dramatically

Industry dominates the total U.S. investment in R&D, with about two-thirds of R&D performed by private firms. As a 60-year trend, industry's share of R&D funding, relative to that of the Federal Government, has risen almost continuously (Figure 3-2). However, the nature of industry R&D has evolved dramatically over the past two decades in ways that may be putting basic research, the seed corn of the entire S&T enterprise, at risk. Put simply, as the larger fraction of R&D has shifted to industry, its time horizon has correspondingly gotten shorter.

Figure 3-2. Ratio of U.S. R&D to Gross Domestic Product, Roles of Federal and Non-Federal Funding for R&D: 1953-2009



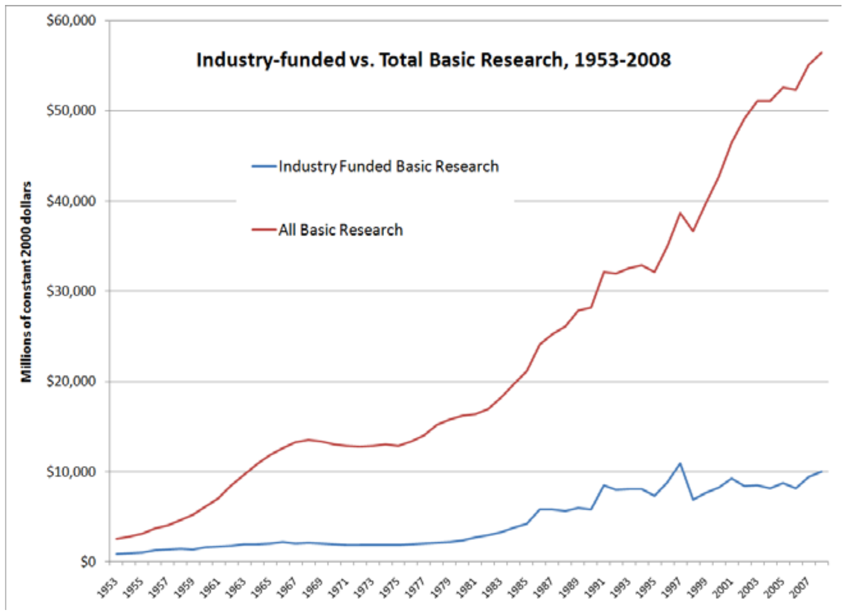
GDP = gross domestic product.

NOTES: Some figures involve estimates and may later be revised. Federal R&D/GDP ratios represent federal government as a funder of R&D by all performers; nonfederal ratios reflect all other sources of R&D funding.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources.

Note: Since the 1960s, total expenditures on R&D have grown with the U.S. economy, so that its ratio to GDP has not dramatically changed. However, the Federal share has decreased significantly, with the balance taken up by industry.

Figure 3-3. Industry Funded and Total Basic Research, 1953–2008



Note: Since the 1990s, industry funding of basic research has remained relatively flat, while total basic research, largely Federally supported, has continued to grow with the U.S. GDP. Data source: NSF, "National Patterns of R&D Resources: 2008 Data Update" wan's NSC Science and Technology Parks, and the Zhongguancun Science Park ("China's Silicon Valley") in Beijing, the home of Lenovo.[188]

PPPs in the United States have long been supported through mechanisms such as the Small Business Innovation Research (SBIR) program and Federal technology-transfer processes but have not reached the level of funding of the prominent foreign examples previously cited. NIH's recent establishment of a new National Center for Advancing Translational Sciences (NCATS), whose programs involve a national consortium of medical research institutions,[189] is a positive step. We consider public-private partnerships a ripe area for further investment, especially with university participation and leadership.

6.4 Engaging on National Workforce Issues

Action #5.4. Confront difficult career-development and workforce issues, including length of time to Ph.D. and the reliance of the S&T enterprise on the labor of early career training positions.

The United States is the world leader in basic research, performed at universities, Federal laboratories, and independent research institutes; led by principal investigators, university faculty, and laboratory staff; and populated by graduate students, postdoctoral researchers, and other research staff. The high standing of U.S. universities, research institutes, and laboratories derives both from the quality of the graduate programs (i.e., the training of students as researchers) and from the quality and volume of research results, measured by publications in leading journals, citations, patents, etc.

Indeed, the research enterprise depends on the relatively inexpensive labor provided by students and post-doctoral scholars. These early career scientists are a crucial part of the U.S. research enterprise. This dependence creates a potential conflict between the need to maintain the size of this early career workforce and the need to advance the careers of the talented researchers who will keep the American research ecosystem the most productive in the world. While compensation should reflect the nature of junior positions as researchers in training, the issues of graduate student and postdoctoral researcher numbers and the duration of doctoral programs and postdoctoral appointments are serious ones that need to reflect realistic expectations for future career opportunities. We need to be training people for science and engi-

[188] We can add further examples: the University of Dundee's "Dundee Kinase Consortium" in the U.K., and in the United States, on a smaller scale, the Alzheimer's Disease Neuroimaging Initiative, the Biomarker Consortium, the Cardiac Safety Research Consortium, the Patient Reported Outcomes Consortium, the Analgesic Clinical Trials Innovation Opportunities and Network (ACTION), the Predictive Safety Consortium, and the Serious Adverse Events Consortium.

[189] NIH NCATS, "Clinical and Translational Science Awards," at www.ncats.nih.gov/research/cts/ctsa/ctsa.html