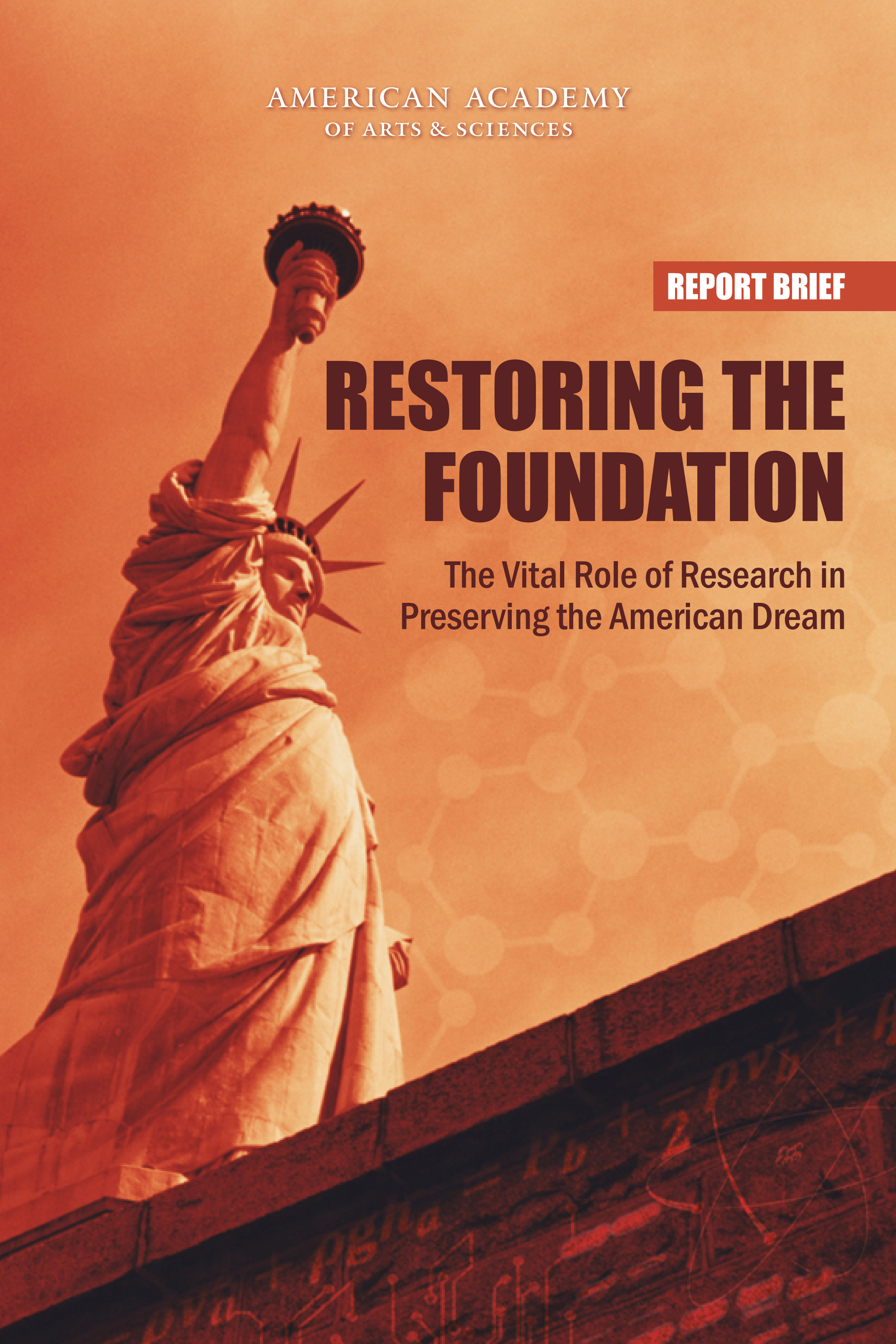
AMERICAN ACADEMY
OF ARTS & SCIENCES

REPORT BRIEF

# RESTORING THE FOUNDATION

## The Vital Role of Research in Preserving the American Dream



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AMERICAN ACADEMY OF ARTS & SCIENCES
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*The American Academy dedicates this report to the memory of Charles M. Vest, one of America's leading advocates for science, engineering, and higher education. Among his many contributions, Dr. Vest served as Cochair of the Academy's oversight committee on Science, Engineering & Technology. His life embodied the American Dream, and his quiet wisdom, vision, and commitment to national service continue to inspire the Academy's work.*

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# Executive Summary

*"Industry's nearly total R&D focus on rapidly commercializing products, when combined with growing constraints on support of university research, could devastate our national innovation system. It could well leave us without a shared, evolving base of new scientific knowledge and new technology.* ***It could destroy the primary source of tomorrow's products, jobs, and health.***

*Many Americans have long been concerned that we [are] mortgaging our children's future with ever-increasing federal budget deficits. Rightly so.* ***We must not, however, foreclose on their future by failing to invest in their education and in the research that will be the basis of their progress."***

– Charles M. Vest, July 18, 1995,
in a speech delivered to the National Press Club[1]

The American research enterprise is at a critical inflection point. The decisions that policy-makers and leaders in science, engineering, and technology make over the next few years will determine the trajectory of American innovation for many years to come.

Recent data show that the United States has slipped to tenth place among OECD (Organisation for Economic Co-operation and Development) nations in overall research and development (R&D) investment as a percentage of GDP,[2] and continues to fall short of the goal of at least 3 percent adopted by several U.S. presidents (Fig. 1A and 1B, pages 3–4). As we lose our global competitive edge, many emerging nations are increasing their research investments in order to stimulate economic growth. Indeed, China is projected to outspend the United

1. Charles M. Vest, "In Search of Mediocrity: Is America Losing its Will To Excel?" speech delivered to the National Press Club, Washington, D.C., July 18, 1995, http://web.mit.edu/president/communications/NPC-7-95.html.

2. Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators*, vol. 2013, no. 2 (Paris: OECD Publishing, 2014), Table 2, "Gross Domestic Expenditures on R&D (GERD) as a Percentage of GDP."

States in R&D within the next ten years, both in absolute terms and as a fraction of economic output.[3] If our nation does not act quickly to shore up its scientific enterprise, it will squander the advantage it has long held as an engine of innovation that generates new discoveries and stimulates job growth.

Innovation relies on breakthrough discoveries that are primarily the products of fundamental, curiosity-driven research. Yet companies – finding it increasingly difficult to justify such long-term investments in a market environment focused on short-term results – have made it clear that the federal government must continue to be the primary funder of basic research. It is therefore worrisome that federal support for basic research has dropped 13 percent below the level measured ten years ago as a percentage of GDP.

Budgetary pressures are only expected to increase. Current budget projections predict that discretionary spending – of which basic research investments are a small percentage – will shrink from 35 percent to 23 percent of the federal budget over the next ten years.[4] Unless basic research becomes a higher government priority than it has been in recent decades, the potential for fundamental scientific breakthroughs and future technological advances will be severely constrained.

Compounding this problem, few mechanisms currently exist at the federal level to enable policy-makers and the research community to set long-term priorities in science and engineering research, bring about necessary reforms of policies that impede progress, or facilitate stronger cooperation among the many funders and performers of research (including universities, corporations, federal and state government, and philanthropic and nongovernmental organizations).

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3. Battelle and *R&D Magazine*, *2014 Global R&D Funding Forecast* (December 2013).

4. Between FY 2013 and FY 2024, the CBO projects that mandatory spending will increase by 80 percent (from $2.032 trillion to $3.664 trillion) while discretionary spending will increase by 15 percent (from $1.202 trillion to $1.380 trillion), resulting in an overall decrease in discretionary spending as a share of the total federal budget. See Congressional Budget Office, *Updated Budget Projections: 2014 to 2024* (Washington, D.C.: Congressional Budget Office, 2014), Table 1, "CBO's Baseline Budget Projections."

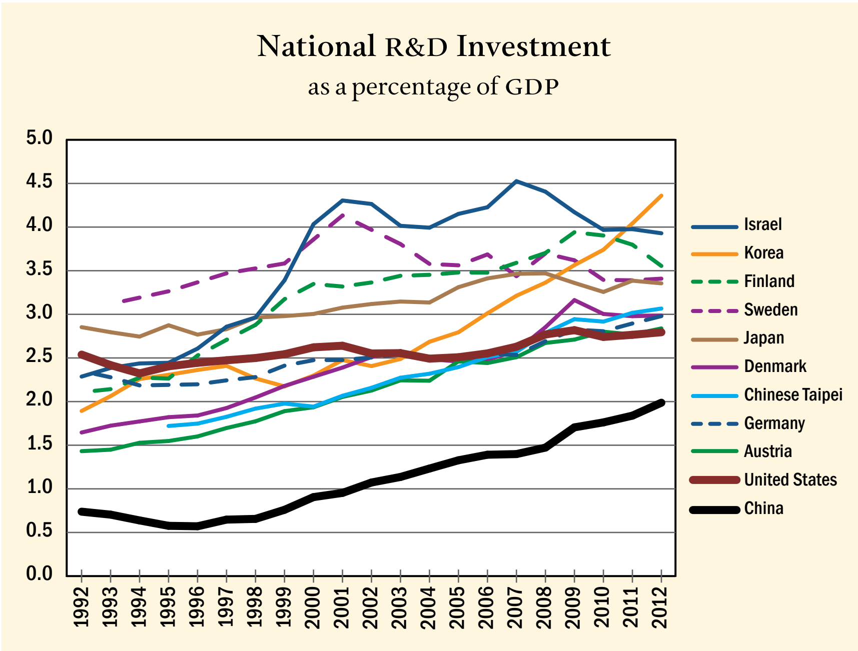


*Figure 1A*

### The United States is Failing to Keep Pace with Competitors' Investments in R&D

As China's R&D intensity (black) rapidly grows by an average of 8 percent per year in pursuit of the goal of R&D investment equal to 3 percent of GDP, U.S. investments (red) have pulled back. At this pace, China will surpass the United States in R&D intensity in about eight years.[5]

Source: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators*, vol. 2013, no. 2 (Paris: OECD Publishing, 2014), Table 2, "Gross Domestic Expenditures on R&D (GERD) as a Percentage of GDP."

5. Battelle and *R&D Magazine*, *2014 Global R&D Funding Forecast* (December 2013).

## The U.S. has Fallen to 10th place in R&D Investment

U.S. ranking among OECD nations by national R&D investment as a percentage of GDP

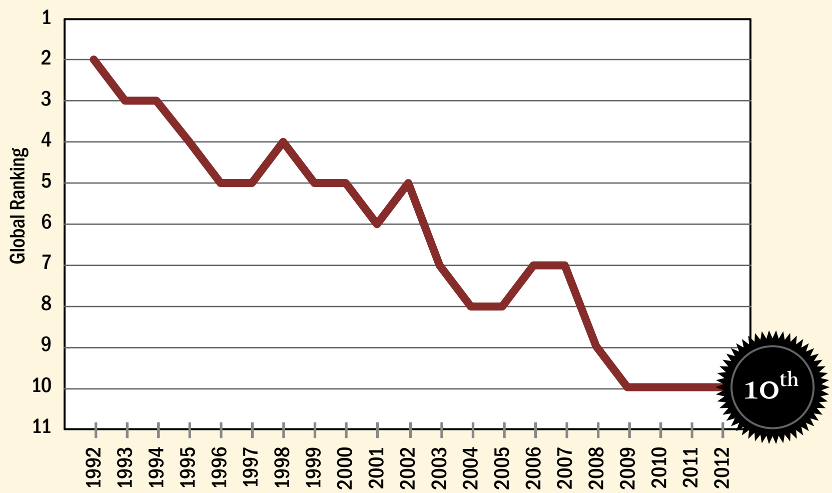


*Figure 1B*

**The United States is Failing to Keep Pace with Competitors' Investments in R&D**

Among OECD nations, the United States ranks tenth in R&D intensity (national R&D investment as a percentage of GDP).

Source: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators*, vol. 2013, no. 2 (Paris: OECD Publishing, 2014), Table 2, "Gross Domestic Expenditures on R&D (GERD) as a Percentage of GDP."

In response to these concerns, the American Academy of Arts & Sciences assembled a committee of recognized leaders from all sectors of science, engineering, and technology, including former CEOs, university presidents and deans, and government officials, to recommend policy actions to help ensure the long-term sustainability of the U.S. science and engineering research enterprise. The committee based its work on three premises: first, that a strong U.S. economy is vital to the welfare and prosperity of the American people; second, that competitiveness in today's accelerating high-tech, knowledge-based economy requires innovation and the rapid infusion of new knowledge and technologies; and third, that while applied research and applied development are both undeniably important, pathbreaking discoveries are most likely to come from basic research sustained over long periods of time, which is mainly funded by the federal government and carried out in the nation's universities and national laboratories.

The committee's recommendations focus on three overarching objectives:

> First, to *secure America's leadership in science and engineering research – especially basic research – by providing sustainable federal investments*.
>
> Second, to *ensure that the American people receive the maximum benefit from federal investments in research*.
>
> Third, to *regain America's standing as an innovation leader by establishing a more robust national government-university-industry research partnership*.

America's economic ascendency in the twentieth century was due in large part – perhaps even primarily – to its investments in science and engineering research. Basic research lies behind every new product brought to market, every new medical device or drug, every new defense and space technology, and many innovative business practices. To match the increasing pace of technological advancement across the globe, the United States must accelerate both the discovery of new scientific knowledge and the translation of that knowledge to useful purpose. Failure to act now could threaten the very principles – opportunity, social mobility, innovation – that have inspired our nation for the past century.

## THE AMERICAN DREAM

> *"New frontiers of the mind are before us, and if they are pioneered with the same vision, boldness, and drive with which we have waged this war we can create a fuller and more fruitful employment and a fuller and more fruitful life."*
>
> – Letter from President Franklin D. Roosevelt to Vannevar Bush, November 17, 1944, prompting Vannevar Bush to write the historic report *Science, the Endless Frontier*[6]

The pathway to America's "endless frontier" is clear, but America is not on it.

For nearly two centuries, individuals throughout the world have been inspired by the American Dream. At its best, the Dream has implied opportunity for everyone, no matter his or her parents' socioeconomic status. It has been underpinned by America's freedom and democracy, and it has promised economic well-being to anyone willing to work hard. Education has been an important part of the Dream, embraced as the key to upward mobility even by those who had not been given the opportunity to receive an extensive education themselves. In economic terms, the American Dream has meant having a decent job: not an easy or lucrative job, but one that could provide a livable wage and afford the next generation of Americans the opportunity for a better life than their parents had lived.

Some would, of course, view this scenario as overly idealistic; but millions of people born within this nation and around the world have *lived* the American Dream, including many members of the committee that prepared this report. Even with its imperfections, some of which are not insignificant, people from around the globe have equated the very essence of the United States with the American Dream, and as such this nation has represented a beacon of hope for much of the world.

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6. Franklin D. Roosevelt to Vannevar Bush, November 17, 1944, Washington, D.C., https://www.nsf.gov/od/lpa/nsf50/vbush1945.htm.

Recent surveys conducted in countries around the world indicate that a substantial majority of respondents believe that the primary factor influencing their overall well-being is having an adequate job.[7] Early in this nation's history, such jobs were concentrated in agriculture; but with the advent of the industrial revolution, farming was displaced by manufacturing as the primary source of employment. Today, yet another economic revolution is occurring, driven by globalization and strongly rooted in technological advancement. The development of jet airliners has made it possible to move people and objects around the world nearly at the speed of sound; the development of modern information systems – telecommunications, processors, data storage – has made it feasible to move ideas, knowledge, and information around the world at the speed of light. In this new world, many no longer compete for a job with their neighbors across town; rather, they now compete with job candidates across oceans. These new global neighbors are highly motivated, increasingly well-educated, and often willing to work for a fraction of the wages and benefits to which American workers are accustomed. The consequences of this revolution in job creation have been and will continue to be profound, particularly for unskilled workers. Wages are increasingly being determined within a global labor pool, and many jobs at the lower end of the spectrum are disappearing altogether, often due to the effects of automation.

How is the American Dream faring in this new environment, in which economic competition is both increasingly globalized and increasingly technology-based?

People around the world still seek to come to America's shores in vast numbers, but disconcertingly, surveys reveal that in many countries, respondents no longer name America when asked where they would go to find a better

7. See Jenny Chanfreau, Cheryl Lloyd, Christos Byron, Caireen Roberts, Rachel Craig, Danielle De Feo, and Sally McManus, *Predicting Wellbeing* (London: NatCen Social Research, 2013); Organisation for Economic Co-operation and Development Better Life Initiative, *Compendium of OECD Well-Being Indicators* (Paris: OECD Publishing, 2011); and Gallup-Healthways Well-Being Index, *State of American Well-Being* (Gallup, Inc. and Healthways, Inc., 2014).

life. For the first time in the nation's history, young males in America are less well-educated than their fathers,[8] and they are likely to be less healthy as well.

Further, the overall opportunity gap is widening. The strongest indicator of whether a child will one day receive a college degree is whether or not that child's parents received degrees.[9] Youths in the lower quartile of academic performance whose parents are in the upper economic quartile are more likely to receive a college education than youths in the upper academic quartile whose parents reside in the lower economic quartile.[10] This imbalance poorly serves both the individual and the nation. As a consequence of these and other factors, a majority of Americans now believe that their children will experience an inferior quality of life to that which they themselves enjoyed.[11]

**The predominant driver of GDP growth over the past half-century has been scientific and technological advancement.**

Given the strong correlation of well-being with economic opportunity, the question arises: what must be done in economic terms to help preserve the American Dream? Since there is a strong correlation between job growth and gross domestic product (GDP), job creation on a large scale requires growing the nation's GDP. Numerous studies (one of which helped earn its author a Nobel Prize) have shown that the predominant driver of GDP growth over

8. National Center for Education Statistics, *Literacy in Everyday Life: Results from the 2003 National Assessment of Adult Literacy* (Washington, D.C.: Department of Education, 2007). Results showed that the functional literacy of U.S. males declined between 1992 and 2003.

9. Lumina Foundation, *A Stronger Nation through Higher Education* (Indianapolis, Ind.: Lumina Foundation, 2013).

10. Joshua S. Wyner et al., *Achievement Trap: How America is Failing Millions of High-Achieving Students from Lower-Income Families* (Lansdowne, Va.: Jack Kent Cooke Foundation, 2009).

11. Andrew Kahout, "What Will Become of America's Kids?" Pew Research Center, May 12, 2014, http://www.pewresearch.org/fact-tank/2014/05/12/what-will-become-of-americas-kids/.

the past half-century has been scientific and technological advancement.[12] It is likely, given the current pace of progress in science and technology fields, that this will be equally true in the decades ahead, if not more so.

**Virtually every new technological product is traceable to a research discovery, often one pursued with no application in mind.**

But how is technological advancement created? Where does it originate? The fundamental feasibility of virtually every new technological product is traceable to a research discovery, often one pursued with no application in mind but for the sole purpose of expanding the frontiers of knowledge and understanding. For example, it seems doubtful that scientists exploring phenomena in solid-state physics or quantum mechanics in the mid-1900s executed their research for the express purpose of producing smartphones, laptop computers, global positioning systems (GPS), or imaging weather satellites. It seems equally unlikely that they foresaw the role their work would play in creating jobs for the factory workers, salespersons, accountants, and truck drivers associated with these products. And yet these were some of the many outcomes of their research. If we hope to continue to reap the benefits of research, then we must invest in research and improve the quality of STEM (science, technology, engineering, and mathematics) education at all levels and encourage more American youth to pursue careers in science, engineering, and technology (SE&T).

Innovators and entrepreneurs, many of whom are engineers, are an indispensable catalyst for transforming the results of research into capabilities and technologies that benefit society. But research is the foundation of their achievements and is what enables the creation of the jobs they provide for a broad spectrum of Americans. To expect continued technological advance-

12. Robert M. Solow, "Technical Change and the Aggregate Production Function," *The Review of Economics and Statistics* 39 (3) (August 1957): 312–320. See also George Evans, Seppo Honkapohja, and Paul Romer, "Growth Cycles," *American Economic Review* 88 (3) (1998); and World Economic Forum, *The Global Competitiveness Report 2001–2002* (New York; Oxford: Oxford University Press, 2002).

ment and job growth without investing in research is akin to attempting to operate an automobile factory without a loading dock for steel, aluminum, or rubber. In short, research is the lifeblood of a high-tech economy and plays a critical role in the economic and personal well-being of most citizens.

Research is generally categorized as either "basic" or "applied," with the former seeking to produce new knowledge without any specific application in mind, and the latter focusing on addressing a more specific problem or need. One might further divide basic research itself into two categories: one that is purely curiosity-driven, such as particle physics or astrophysics; and another that is fundamental but also relates to some category of opportunity, such as deciphering the human genome in search of cures for diseases.

**Research is the lifeblood of a high-tech economy and plays a critical role in the economic and personal well-being of most citizens.**

Each category serves an important function, but too often the impact of basic research (as opposed to applied research) has been undervalued. In this regard, Hunter Rawlings, president of the American Association of Universities, cites the iPhone, observing that

> it depends on seven or eight fundamental scientific and technological breakthroughs, such as GPS, multi-touch screens, LCD displays, lithium-ion batteries, and cellular networks. How many of those discoveries were made by Apple? None. They all came from research supported by the federal government and conducted in universities and government laboratories. Apple deserves credit for the final product, but it depends on government-sponsored research, much of it curiosity-driven rather than economically driven.[13]

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13. "Hunter R. Rawlings III Alumni Day Remarks: The Lion in the Path," News at Princeton, Princeton University, February 25, 2014, http://www.princeton.edu/main/news/archive/S39/33/39I39/index.xml?section=topstories.

## America is permitting its highly successful system to atrophy.

Of course, the importance of industrial research and innovation should not be understated, but basic research, most of which is government-funded, is absolutely necessary to cultivate an ecosystem of research rich enough in new knowledge and ideas to enable breakthrough achievements.

The power of America's economic system and the role its universities, industry, and government have played in its growth have not gone unnoticed by other countries competing in the global job market. In fact, these growing powers seek not only to copy but to improve upon the American model. Instead of racing to meet the challenge, America is permitting its highly successful system to atrophy. This is not a formula for success in a highly competitive world.

But beyond the opportunity for economic success, there are other essential ingredients to the American Dream, including, most importantly, the opportunity to live in freedom and in a civil society governed by the rule of law (the province of research in the social sciences). The American Dream also preserves, and is itself sustained by, the opportunity to live a healthy life. In the past century, life expectancy in America grew from forty-nine years to seventy-nine years,[14] with biomedical research a significant contributor to the gain. And Americans now rightly expect that the food they eat, the water they drink, the air they breathe, and the environment they live in will be safe (the domains of agricultural, environmental, and earth sciences). While the American Dream rests on more than research alone, it is clear that the elements forming the foundation of the Dream – economic prosperity, improved quality of life through technology and medicine, opportunity for a quality education and a quality job, the hope of a better life for one's children – would begin to crumble without the vital reinforcement provided by the research enterprise.

14. Elizabeth Arias, "United States Life Tables, 2003," *CDC National Vital Statistics Reports*, vol. 54, no. 14 (revised March 2007), 30–33; and Organisation for Economic Co-operation and Development, *OECD Better Life Index*, "Health – United States," http://www.oecdbetterlifeindex.org/topics/health/.

## THE HEALTH OF AMERICA'S RESEARCH ENTERPRISE

Given the critical role of research in sustaining the American Dream, it is useful to assess the health of the nation's research enterprise. This is not an easy task, particularly given the diversity of that enterprise. Historically, many years elapse between the time when the most basic research is performed and when its impact manifests in the form of newly created products and jobs. Further, research is itself a leading endeavor in the globalization of society such that the attribution of specific scientific accomplishments to a particular country or region is not always straightforward.

This latter circumstance has led some to question why America should not simply adopt a policy of letting other nations pay for the conduct of research and using their results to produce domestic products and jobs. Some nations have successfully employed this strategy in the past, particularly given complacent competitors such as the U.S. automobile industry of the latter part of the twentieth century. However, it will be increasingly difficult to follow such a scheme in the future: the pace of technological innovation is accelerating to the point where being second to market is now considered by many executives to be tantamount to failure. Craig Barrett, the retired CEO of Intel, has noted that 90 percent of the revenues Intel receives at the end of its fiscal year are derived from products that did not even exist at the beginning of that year.[15] Such a system would not work without a rich base of knowledge and discoveries.

**There is a deficit between what America is investing and what it should be investing to remain competitive, not only in research but in innovation and job creation.**

If research is a driver of GDP growth, as the evidence strongly indicates, then one metric of the adequacy of a nation's investment in research is the number of dollars invested in research as a percentage of GDP, relative to

15. "Craig Barrett: Goodbye to Intel," BBC News, updated May 25, 2009, http://news.bbc.co.uk/2/hi/business/8058296.stm.

competitor nations.[16] By this measure of research intensity, the United States has fallen to tenth place among OECD nations.[17] Several major nations have been increasing their investment in research as a percentage of GDP at a rate considerably surpassing that of the United States. Further, U.S. investment in basic research as a percentage of GDP has actually declined over the past decade. Even government funding of biomedical research, generally strongly supported by the public because of its impact on health, has declined by 13 percent in real terms since 2003, when the effort to strengthen that endeavor began to wane.[18] These disturbing trends have created a deficit between what America is investing and what it should be investing to remain competitive, not only in research but in innovation and job creation. This "innovation deficit"[19] must be closed if we are to improve our global competitiveness and strengthen our economy.

How does one determine how much research is enough? There are, of course, many possible measures of research, both input and output. Perhaps the most fundamental of these is simply the number of capable researchers whose work is adequately funded. From a purely statistical standpoint, this measure would seem to favor nations with larger populations. But there is far more to the issue than sheer numbers of researchers: one thousand good researchers are unlikely to produce the work of one Albert Einstein. Quality and selectivity matter, and America's tradition of awarding funding based on expert peer-review evaluation of competitive research proposals has been key to the nation's past leadership in many fields of research.

Four significant sources of research funding exist in America: government (both federal and state), industry, universities, and philanthropy. In recent decades, as government reduced its share of the nation's investment in R&D

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16. This research investment could alternatively be stated as the number of dollars of GDP that each dollar invested in research must support.

17. OECD, *Main Science and Technology Indicators*, Table 2, "Gross Domestic Expenditures on R&D (GERD) as a Percentage of GDP."

18. American Association for the Advancement of Science, R&D Budget and Policy Program, "Trends in Research by Agency, 1976 – 2015," *Historical Trends in Federal R&D*, http://www.aaas.org/page/historical-trends-federal-rd (accessed August 15, 2014).

19. See http://www.innovationdeficit.org/.

from two-thirds to one-third, industry increased its share from about one-third to about two-thirds. But industry, given its need to react to the pressures of impatient financial markets, has concentrated its focus on *D* at the expense of *R*, with the demise of the iconic Bell Labs being a disconcerting example. This could be equated with eating one's seed corn without planting any for next year's harvest.

**It is important when making allocation decisions to distinguish between spending for present consumption and spending for investment.**

Similarly, as state support for the nation's great public research universities has declined precipitously during the past decade, these institutions now find themselves in no position to substantially increase their research pursuits. In the United States, philanthropy is an important source of funding in specific areas of science, and although it continues to grow, philanthropy still makes up a small portion of the national research investment.[20]

This leaves the federal government as the essential funder for research that is conducted on a globally competitive scale but may not be driven by strong market incentives. It would seem to be a natural responsibility of government to support endeavors that clearly serve the public good, but which private entities are unable or unwilling to adequately support. Although America today faces a serious challenge in the form of its large national debt, it is important when making allocation decisions to distinguish between spending for present consumption and spending for investment, the latter being essential to the nation's future prosperity.

Research clearly represents an investment in the future. The need for a major federal role in funding research becomes all the more compelling given the evolution that has occurred across virtually all fields of research. To a sub-

20. Fiona Murray, "Evaluating the Role of Science Philanthropy in American Research Universities," National Bureau of Economic Research Working Paper No. 18146 (June 2012), 23.

stantial degree, the conduct of research has morphed from one scientist working in a laboratory to large teams of researchers working in a wide variety of fields, using sophisticated and expensive instrumentation, equipment, and informatics.

The most successful and widely emulated model for sustaining America's research enterprise has been and continues to be one wherein the primary funder of research, particularly basic (curiosity-driven or discovery-based) research, is the federal government, and the principal performers are the nation's universities, research institutes, and federal research laboratories. The translation of the results of this effort into jobs for the nation's citizenry will continue to be the responsibility of innovators, entrepreneurs, and the industrial sector. But if this translation is to be realized, the presently fractured links among government, industry, and academia in the United States must be greatly strengthened. Existing barriers to cooperation must be removed and the movement of individuals among these three sectors must be facilitated, since the most effective form of technology transfer is often the transfer of people.

## PRESCRIPTIONS FOR THE FUTURE HEALTH OF THE SCIENCE AND ENGINEERING RESEARCH ENTERPRISE

Given the above considerations, the American Academy of Arts & Sciences formed a committee composed of individuals with backgrounds in academia, industry, and government to offer recommendations that would strengthen the nation's competitiveness in the global job market through a revitalized research enterprise. The result was the formulation of three overarching prescriptions combined with a series of implementing actions. These recommendations are summarized below; additional background and observations related to each recommendation can be found in chapter three of the full report.

# Prescription 1

## Secure America's Leadership in Science and Engineering Research – Especially Basic Research – by Providing Sustainable Federal Funding and Setting Long-Term Investment Goals

ACTION 1.1 – We recommend that the President and Congress work together to establish a sustainable real growth rate of *at least* 4 percent in the federal investment in basic research, approximating the average growth rate sustained between 1975 and 1992 (see Fig. 2, page 18). This growth rate would be compatible with a target of at least 0.3 percent of GDP for federally supported basic research by 2032 (one-tenth the national goal for combined public and private R&D investment adopted by several U.S. presidents). We stress that an increase in support for basic research should not come at the expense of investments in applied research or development, both of which will remain essential for fully realizing the societal benefits of scientific discoveries and new technologies that emerge from basic research.

We further recommend that, as the U.S. economy improves, the federal government strive to exceed this growth rate in basic research, with the goal of returning to the sustainable growth path for basic research established between 1975 and 1992.

Productive first steps include:

- Establishment of an aggressive goal of *at least* 3.3 percent GDP for the total national R&D investment (by all sources) and a national discussion of the means of attaining that goal;
- Strong reauthorization bills, following the model set by the 2007 and 2010 America COMPETES Acts,[21] that authorize the investments necessary to renew America's commitment to science and engineering research and STEM education and reinforce the use of expert peer review in determining the scientific merit of competitive research proposals in all fields;

21. *America COMPETES Act,* Public Law 110-69, H.R. 2272, 110th Congress (January 4, 2007); and *American COMPETES Reauthorization Act of 2010,* Public Law 111-358, H.R. 5116, 111th Congress (January 4, 2011).

- Appropriations necessary to realize the promise of strong authorization acts; and
- A "Sense of the Congress" resolution affirming the importance of these goals as a high-priority investment in America's future.

ACTION 1.2 – We recommend that the President and Congress adopt *multi-year appropriations* for agencies (or parts of agencies) that primarily support research and graduate STEM education. Providing research agencies with advanced notice of pending budgetary changes would allow them to adjust their grant portfolios and the construction of new facilities accordingly. The resulting efficiency gains would reduce costs while enhancing research productivity.

ACTION 1.3 – We recommend that the White House Office of Management and Budget (OMB) establish a *strategic capital budget process* for funding major research instrumentation and facilities, ideally in the context of a broader national capital budget that supports investment in the nation's infrastructure; and that enabling legislation specifically preclude earmarks or other mechanisms that circumvent merit review.

ACTION 1.4 – We recommend that the President include in the annual budget request to Congress a rolling long-term (five-to-ten-year) plan for the allocation of federal R&D investments – especially funding for major instrumentation that requires many years to plan and build.

Recapturing American competitiveness in innovation will require that federally funded research, particularly basic research, become a higher priority than it has been over the past two decades. From 1975 to 1992, the federal investment in basic research grew at an average annual inflation-adjusted rate of 4.4 percent (see Fig. 2, page 18), despite serious political and economic challenges, including the 1973 oil embargo, the Great Inflation of 1979–1982, and the final tumultuous years of the Cold War. During this period, Republicans and Democrats, in spite of a number of policy differences, were in agreement that federal funding of basic research was a priority for the nation.

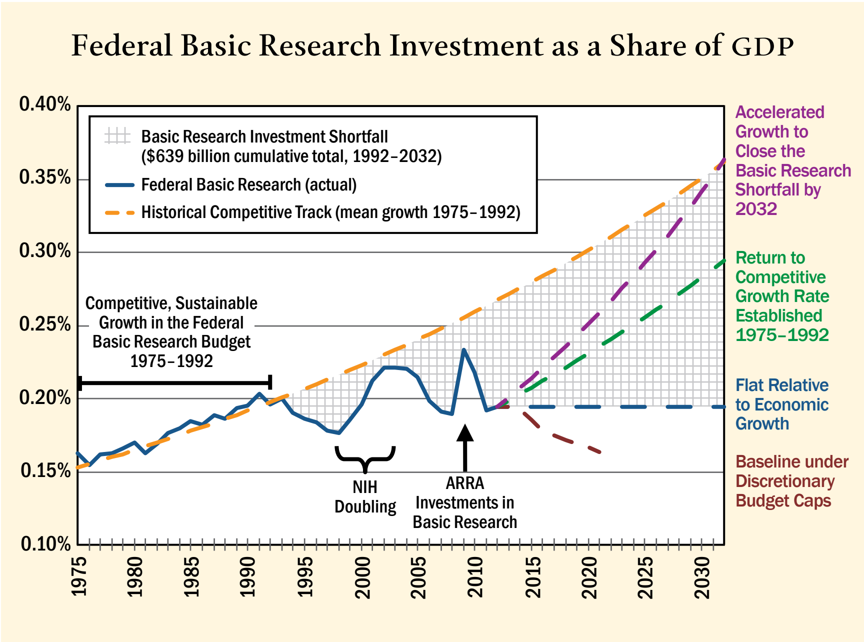


*Figure 2*

## Getting U.S. Basic Research Back on Track

Should federal obligations for basic research (blue) flatline relative to economic growth, the United States will by 2032 have accumulated a $639 billion shortfall (cross-hatch) in federal support of basic research relative to the 4.4 percent average annual real growth trend (orange) established during the period of 1975 to 1992. This committee recommends that the nation return to this historical competitive growth rate (green), with the ultimate goal of fully closing the basic research shortfall (purple) as the economy improves.

Refer to Appendix C in the full report to view this graph in constant dollars.

Data Sources: Federal obligations for basic research from 1975 to 2012 are from the National Science Board, *Science and Engineering Indicators 2014* (Arlington, Va.: National Science Foundation, 2014), Appendix Table 4-34, "Federal Obligations for R&D and R&D Plant, by Character of Work: FYs 1953–2012." Basic research funding baseline projections are based on the nondefense discretionary funding levels from Office of Management and Budget, *Fiscal Year 2015 Budget of the U.S. Government* (Washington, D.C.: Office of Management and Budget, 2014), Table S-10, "Funding Levels for Appropriated ('Discretionary') Programs by Category," whose baseline levels assume Joint Committee enforcement cap reductions are in effect through 2021. GDP projections assume an average real annual growth rate of 2.2 percent until 2020 and 2.3 percent from 2020 to 2030, according to Jean Chateau, Cuauhtemoc Rebolledo, and Rob Dellink, "An Economic Projection to 2050: The OECD 'ENV-Linkages' Model Baseline," *OECD Environment Working Papers*, No. 41 (Paris: OECD Publishing, 2011), Table 4, doi:10.1787/5kgondkjvfhf-en.

# Prescription 2

## Ensure that the American People Receive the Maximum Benefit from Federal Investments in Research

ACTION 2.1 – We recommend that the President publish a biennial "State of American Science, Engineering & Technology" report giving the administration's perspective on issues such as those addressed by the *Science and Engineering Indicators* and related reports published by the National Science Foundation (NSF) National Science Board (NSB),[22] and with input from the federal agencies that sit on the President's National Science and Technology Council (NSTC). The report, if released with the President's budget, would provide information useful for both the appropriations and authorization legislative processes.

ACTION 2.2 – We recommend the following actions to enhance the productivity of America's researchers, particularly those based at universities:

> ACTION 2.2a – We recommend that the White House Office of Science and Technology Policy and Office of Management and Budget lead an effort to streamline or eliminate practices and regulations governing federally funded research that have become burdensome and add to the universities' administrative overhead while failing to yield appreciable benefits.
>
> ACTION 2.2b – We recommend that universities adopt "best practices" targeted at capital planning, cost-containment efforts, and resource sharing

22. The statutory authority of the NSB is included under U.S. Code 42, Chapter 16, Paragraph 1863, http://www.law.cornell.edu/uscode/text/42/chapter-16: "Report to President; submittal to Congress: (1) The Board shall render to the President and the Congress no later than January 15 of each even numbered year, a report on indicators of the state of science and engineering in the United States; (2) The Board shall render to the President and the Congress reports on specific, individual policy matters within the authority of the Foundation (or otherwise as requested by the Congress or the President) related to science and engineering and education in science and engineering, as the Board, the President, or the Congress determines the need for such reports."

with outside parties, such as those described in the 2012 National Research Council (NRC) report *Research Universities and the Future of America*.[23]

**ACTION 2.2c** – We recommend that universities and the National Institutes of Health (NIH) gradually adopt practices to foster an appropriately sized and sustainable biomedical research workforce.[24] Key goals should include reducing the length of graduate school and postdoctoral training and shifting support for education to training grants and fellowships; providing funding for master's degree programs that may provide more appropriate training for some segments of the biomedical workforce now populated by Ph.D.s; enhancing the role of staff scientists in university laboratories and core facilities; reducing the percentage of faculty salaries supported solely by grants; and securing a renewed commitment from senior scientists to serve on review boards and study sections.

**ACTION 2.2d** – We recommend that the President and Congress reaffirm the principle that competitive expert peer review is the best way to ensure excellence. Hence, peer review should remain the mechanism by which federal agencies make research award decisions, and review processes and criteria should be left to the discretion of the agencies themselves. In the case of basic research, scientific merit – based on the opinions of experts in the field – should remain the primary consideration for awarding support.

**ACTION 2.2e** – We recommend that the research funding agencies intensify their efforts to reduce the time that researchers spend writing and reviewing proposals, such as by expanding the use of pre-proposals, providing additional feedback from program officers, allowing authors to respond to reviewers' comments, further normalizing procedures across the federal government, and experimenting with new approaches to streamline the grant process.

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23. National Research Council, *Research Universities and the Future of America: Ten Breakthrough Actions Vital to Our Nation's Prosperity and Security* (Washington, D.C.: The National Academies Press, 2012).

24. While the situation is particularly acute for the biomedical research workforce, mismatches between supply and demand also exist in other fields, such as computer science. Therefore, other federal agencies might also examine how their programs and priorities affect the workforce.

ACTION 2.3 – We recommend that the National Academies, the American Association for the Advancement of Science (AAAS), and the American Academy of Arts & Sciences convene a series of meetings of nongovernmental organizations and professional societies that focus on science and engineering research, for the purpose of establishing a formal task force, alliance, or new organization to:

- Develop a common message about the nature and importance of science and engineering research that could be disseminated by all interested organizations;
- Elevate science and technology issues in the minds of the American public, business community, and political figures, and restore appropriate public trust;
- Ensure that the recommendations offered by existing science and technology policy organizations, academies, and other advisory bodies remain current and available to institutional leaders and policymakers in all sectors;
- Cooperate with organizations that are focused on business and commerce, national and domestic security, education and workforce, health and safety, energy and environment, culture and the arts, entertainment, and other societal interests and needs to encourage a discussion of the role of science, engineering, and technology in society; and
- Offer assistance – in real time – to federal and state government, universities, private foundations, and leaders in business and industry to help with implementation of policy reforms.

ACTION 2.4 – In order to have direct access to current information and analysis of important science and technology policy issues, we urge Congress to: 1) significantly expand the science, engineering, and technology assessment capabilities of the Government Accountability Office (GAO), including the size of the technical staff, or alternatively to establish and fund a new organization for that purpose; and 2) explore ways to tap the expertise of American researchers in a timely and non-conflicted manner. In particular, consideration should be given to ways in which either the GAO or another organization with scientific and technical expertise could use crowdsourcing and participatory technology assessment to rapidly collect research, data, and analysis related to specific scientific issues.

# Prescription 3

## Regain America's Standing as an Innovation Leader by Establishing a More Robust National Government-University-Industry Research Partnership

ACTION 3.1 – We recommend that the President or Vice President convene a "Summit on the Future of America's Research Enterprise" with participation from all government, university, and industry sectors and the philanthropic community. The Summit should have the bold action agenda to: assess the current state of science and engineering research in the United States in a global twenty-first-century context; review successful approaches to bringing each sector into closer collaboration; determine where further actions are needed to encourage collaboration; and form a new compact to ensure that the United States remains a leader in science, engineering, technology, and medicine in the coming decades.

ACTION 3.2 – We recommend that the nation's research universities:

- Experiment with new intellectual property policies and practices that favor the creation of stronger research partnerships with companies over the maximization of revenues;
- Adopt innovative models for technology transfer that can better support the universities' mission to produce and export new knowledge and educate students;
- Enhance early exposure of graduate students (including doctoral students) to a broad range of non-research career options in business, industry, government, and other sectors, and ensure that they have the necessary skills to be successful;
- Expand professional master's degree programs in science and engineering, with particular attention to students interested in non-research career options; and
- Increase permeability across sectors through research collaborations and faculty research leaves.

ACTION 3.3 – We recommend that the President and Congress, in consultation with leaders of the nation's research universities and corporations, consider legislation to remove lingering barriers to university-industry research cooperation, and specifically:

- Help universities overcome impediments to experimenting with new technology transfer policies and procedures that emphasize objectives (such as the creation of new companies and jobs), outcomes, and best practices (such as processes that minimize the time and cost of licensing); and
- Amend the U.S. tax code to encourage closer university-industry cooperation. For example, in the case of industry-funded research conducted in university buildings financed with tax-exempt bonds, the tax code should be amended to allow universities to enter into advance licensing agreements with industry.

ACTION 3.4 – We recommend that the federal agencies that operate or provide major funding for national laboratories[25] review their current missions, management, and operations, including the effectiveness of collaborations with universities and industry, and phase in changes as appropriate. While consultation with these laboratories is critical in carrying out such reviews, the burden of reviews and other agency requirements is already heavy and should, over time, be reduced.

ACTION 3.5 – We recommend that corporate boards and chief executives give higher priority to funding research in universities and work with university presidents and boards to develop new forms of partnership: collaborations that can justify increased company investments in university research, especially basic research projects that provide new concepts for translation to application and are best suited for training the next generation of scientists and engineers.

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25. As used here, *national laboratories* include intramural laboratories and centers at the Department of Energy (DOE), Department of Defense (DOD), National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA), National Institute of Standards and Technology (NIST), United States Department of Agriculture (USDA), and the National Institutes of Health (NIH).

**ACTION 3.6** – We strongly urge Congress to make the Research and Experimentation (R&E) Tax Credit permanent, as recommended by the President's Council of Advisors on Science and Technology (PCAST), the National Academies, the Business Roundtable, and many others. Doing so would provide an incentive for industry to invest in long-term research in the United States, including collaborative research with universities such as that recommended under Action 3.5.

**ACTION 3.7** – We support the recommendation made by many other organizations, including the President's Council of Advisors on Science and Technology and the National Academies,[26] both to increase the number of H-1B visas and to reshape policies affecting foreign-born researchers in order to attract and retain the best and brightest researchers. Productive steps include allowing foreign students who receive a graduate degree in STEM disciplines from a U.S. university to receive a green card (perhaps contingent on receiving a job offer) and stipulating that each employment-based visa automatically covers a worker's spouse and children.

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26. See President's Council of Advisors on Science and Technology, *Transformation and Opportunity: The Future of the U.S. Research Enterprise* (Washington, D.C.: Executive Office of the President of the United States, 2012); Institute of Medicine, National Academy of Sciences, and National Academy of Engineering, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (Washington, D.C.: The National Academies Press, 2007); and National Research Council, *Research Universities and the Future of America*.

# Conclusion

The American Dream is a national ethos whose foundation is rooted in opportunity: the opportunity for a quality job, a quality life, and a quality education; the opportunity for our children to achieve more than we could and enjoy a better life than we experienced. It imbues the nation with a spirit of hard work and determination. Without opportunity, the Dream fades, and with it goes a key part of our identity as a nation.

These core opportunities are also interconnected: if one fails, the others will follow. Quality of life and well-being rely to a large extent on having a quality job, and both are bound to the health of the nation's economy. Studies have shown that the predominant driver of economic growth over the past half-century has been scientific and technological advancement, the foundation of which is basic, discovery-based research. The federal government is the primary funder of basic research in this country, and is the only reliable source of support for basic research at this scale.

Basic research replenishes a pool of knowledge and ideas that grows new products and processes that benefit the American people and strengthen the economy. This process of innovation is not linear, but rather forms a highly interconnected web that engages not only the federal government and universities, but also business, industry, state governments, and philanthropy. If the United States is to take full advantage of this unparalleled period of rapid scientific and technological advancement, then this complex system of research and invention must thrive.

The recommendations presented in this report, if acted upon, will move the nation from gliding to propelling research, from an unguided to a strategic enterprise, and from a short-term to a long-term focus by establishing a more robust twenty-first-century research partnership across all sectors and by securing American competitiveness through sustainable federal funding for basic research. It is our hope that Americans from all backgrounds and professions will work together to achieve these goals and ensure that our nation and its citizens continue to thrive for generations to come.

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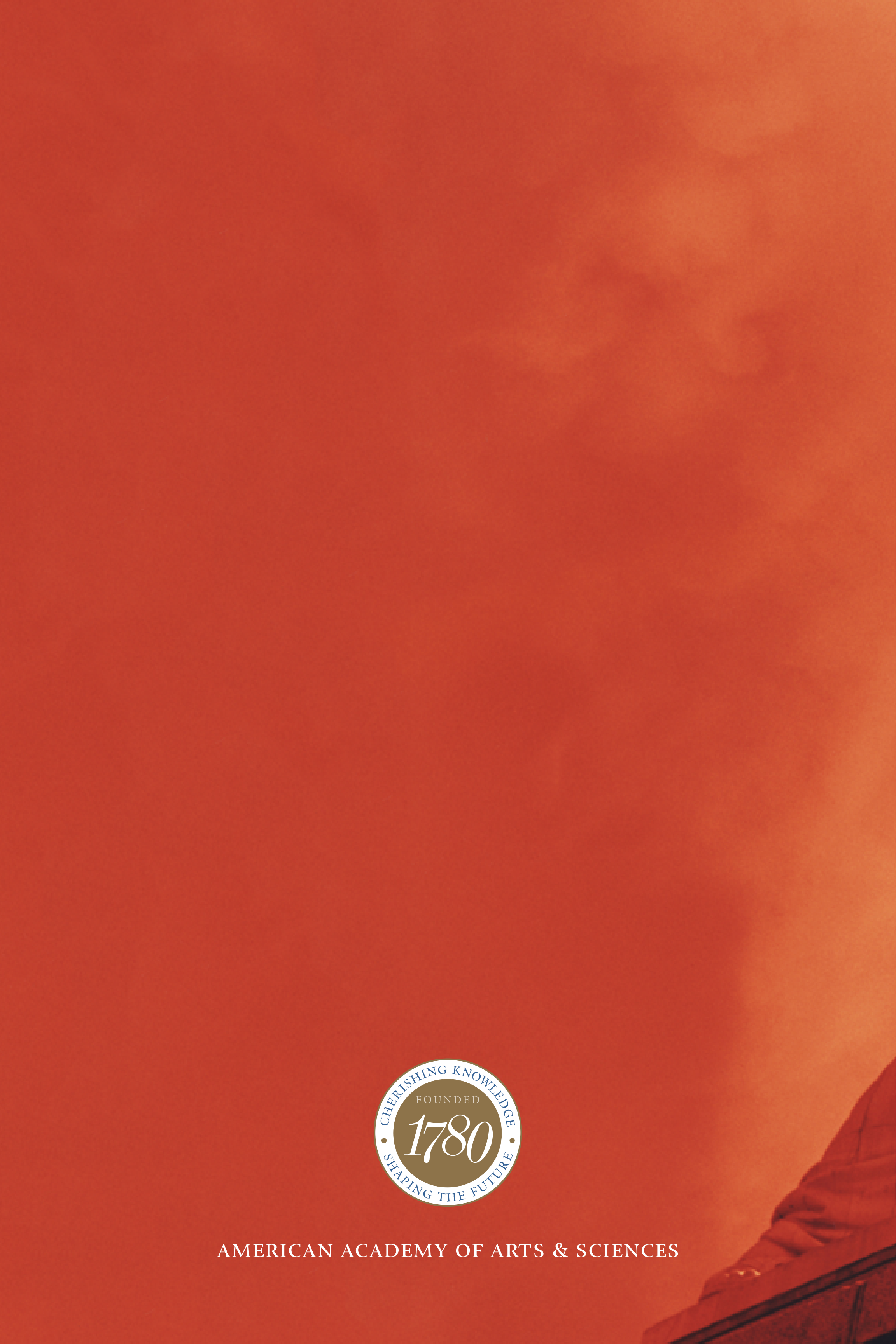

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