Advance Praise for *Science, the Endless Frontier*

"Rush Holt gives new life to Vannevar Bush's seminal report *Science, the Endless Frontier* by emphasizing its continued relevance to American science policy and raising issues that need reexamination—in particular, the relationship between the scientific enterprise and civil society. This is an important read for everyone who is deeply concerned about the status of science in today's discourse."

—Ernest J. Moniz, Massachusetts Institute of Technology and former U.S. Secretary of Energy

"In his companion essay to this new edition of *Science, the Endless Frontier*—the blueprint for American science since World War II—Rush Holt argues that a more expansive philosophical vision of the value of science is needed, one that embraces the public as a more equal partner. Hoorah for Holt, for having the courage to take on this important, timely issue."

—Naomi Oreskes, author of *Why Trust Science?*

"Vannevar Bush's *Science, the Endless Frontier* remains the touchstone for understanding how Americans regard basic research, why they pay for it, and what benefits they expect. These issues are more urgent than ever.

Science, the Endless Frontier

VANNEVAR BUSH

With a companion essay by

RUSH D. HOLT

Science, the Endless Frontier. A Report to the President by Vannevar Bush, Director of the Office of Scientific Research and Development, July 1945 (United States Government Printing Office, Washington: 1945). https://www.nsf.gov/about/history/vbush1945.htm

Published by Princeton University Press
41 William Street, Princeton, New Jersey 08540
6 Oxford Street, Woodstock, Oxfordshire OX20 1TR

press.princeton.edu

Library of Congress Cataloging-in-Publication Data
Names: Bush, Vannevar, 1890–1974, author. | Holt, Rush Dew, 1948–, author. | Princeton University Press.
Title: Science, the endless frontier / Vannevar Bush, Rush D. Holt.
Description: Princeton : Princeton University Press, [2021] | Includes bibliographical references.
Identifiers: LCCN 2020028356 (print) | LCCN 2020028357 (ebook) | ISBN 9780691186627 (hardback) | ISBN 9780691201658 (ebook)
Subjects: LCSH: Science and state—United States. | Research—United States.
Classification: LCC Q127.U6 B88 2021 (print) | LCC Q127.U6 (ebook) | DDC 338.973/06–dc23
LC record available at https://lccn.loc.gov/2020028356
LC ebook record available at https://lccn.loc.gov/2020028357

British Library Cataloging-in-Publication Data is available

Editorial: Jessica Yao, Arthur Werneck, and Maria Garcia
Production Editorial: Kathleen Cioffi
Text Design: Carmina Alvarez
Jacket Design: Amanda Weiss
Production: Jacqueline Poirier
Publicity: Sara Henning-Stout and Katie Lewis
Copyeditor: Erin Hartshorn

This book has been composed in Miller

Printed on acid-free paper. ∞

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

Contents

Science, the Endless Frontier

The Science Bargain

RUSH D. HOLT

to radar, high-performance aircraft, proximity fuses for detonating munitions, and the atom bombs that would ultimately bring the war to a close. Bush oversaw this large and successful research and development enterprise as Roosevelt's informal science adviser and "Czar of Research."[2] As the end of the war came into view, he was one of many political and academic leaders contemplating how Americans could continue to reap the benefits of scientific research in peacetime. In late 1944, he received a request from Roosevelt to prepare a report that, he hoped, would lay the foundations of a lasting American science policy.

Written using input from dozens of prominent scientists and engineers, the resulting report was delivered to President Truman in July 1945, following President Roosevelt's death. As Bush wrote in the report, there had never before been a "national policy" to assure scientific progress. There was a deep respect in American culture

for scientific empirical thinking and practical technology, and there had been government sponsorship of world-renowned scientific work from the Lewis and Clark expedition to military and civilian advances in geology, agriculture, medicine, astronomy, physics, and many other areas. But there had never been a central effort to support the broad scientific enterprise, nor a comprehensive appreciation of what science could contribute to American social and political advancement.

Science, the Endless Frontier presented an inspirational utilitarian vision of what science can bring to people. Invoking a classic theme in American culture, Bush wrote in his letter of transmittal, "The pioneer spirit is still vigorous within this nation. 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." Welcomed by the scientific establishment, the report called on government to promote and support scientific research—especially basic research—and for a new independent national agency amply funded to oversee all research, military and civilian, biological, medical and physical, basic and applied, theoretical and experimental. It would ensure stable funding for long-term contracts and freedom of inquiry for scientists, and it would have the responsibility for the education of scientific specialists. In 1950, after years of debate, Congress would pass the National Science Foundation Act to create "a national policy for the promotion of basic research and education in the sciences," and to support through grants and contracts "basic scientific research in the mathematical, physical, medical, biological, engineering, and other sciences."

Science, the Endless Frontier is now known as the "seminal report" on American science policy,[3] hailed for leading to the "American postwar consensus" for the support of science,[4] and "one of the most influential policy documents in the nation's history."[5] Although various other individuals and organizations also influenced the emerging federal policy for science, the Bush report precipitated the debate that led to an unwritten policy that fostered decades of astounding progress of science. To consider the scientific landscape today one could well begin with an appreciative reading of the Bush report. Many of the issues raised are, in one form or another, still with us. The outcomes it shaped have both contributed to the brilliant scientific enterprise we see today and also cast shadows that our present moment has thrown into sharp relief. They deserve a closer look from today's perspective, to consider again what society needs that science could help to provide.

* * *

In *Science, the Endless Frontier* Bush laid out a strong, specific vision for the role of science in society that today receives at least partial credit for shaping several essential aspects of our modern scientific enterprise and how it functions. This vision was founded in several core ideas that informed Bush's recommendations and the apparatus that eventually emerged from the ensuing debate and legislation.

Most basically—and perhaps most famously—Bush made a powerful case that "scientific progress is essential," and without it "no amount of achievement in other directions can insure our health, prosperity, and security." Advances in science, Bush argued, could offer far-reaching benefits to individuals and to society as a whole, including "more jobs, higher wages, shorter hours, more abundant crops, more leisure for recreation, for study, for learning how to live

has influenced much of federal funding up to the present. Although the report did not actually illustrate research and development with a one-dimensional line, Bush nonetheless clearly shared this common view. Basic research was valuable to Bush *because* it would drive the process toward tangible and practical outputs to meet all national needs.[7]

The Bush report located this research primarily in colleges and universities, to be conducted by trained scientists—the "small body of gifted men and women who understand the fundamental laws of nature." During the Second World War, Bush, with funding through the research agencies he headed, had shown that universities could produce powerfully relevant work quickly, even military weapons and systems. Placing research in universities made it possible in his post-war plans to greatly increase government funding without a proportional increase in the size of government. Bush was tolerant of na-

tional labs but had a low opinion of research directed by the military. Recommending that universities host the research was his hedge against both large government and science directed by the generals. In Bush's view, research was done better by the "voluntary collaboration of independent men." In universities, he saw a unique setting where "scientists may work in an atmosphere which is relatively free from the adverse pressure of convention, prejudice, or commercial necessity," provided with "a strong sense of solidarity and security, as well as a substantial degree of personal intellectual freedom."

Bush believed strongly that science should be guided by scientists. As presented in the report, his plan granted the scientific establishment the authority to choose what scientific projects to undertake. The new agency he proposed was to be overseen by a board of distinguished scientists, and the director was to be chosen by those representatives of the science establishment.

This was a critical part of his vision—in a sense, the defining one, but at the time Bush prepared *Science, the Endless Frontier*, his was not the only vision on the table.

Almost two years before, Senator Harley Kilgore, a first-term Democratic New Dealer from West Virginia, had introduced legislation "to create a central independent agency of government devoted exclusively to the progress and expansion of science and technology, first to win the war and later to contribute to the peace."[8] The proposed agency would coordinate all government research activities. Kilgore compared such strong government centralization and planning to public control of water and power systems, public schools, and public lands, all of which he regarded favorably. At the time, Bush had come out against the bill, believing that research should have no government "command and control" after the war.[9] Bush's aversion to Kilgore's legislative approach, which was gain-

ing support, and his belief that research is more productive under control of scientists themselves led him to write the report.[10] Soon after the Bush report, Senator Kilgore had a full legislative plan for a national program of scientific research.[11]

The structural similarities between Kilgore's plan and Bush's were greater than the differences. Both men thought science was greatly underappreciated, underfunded, and uncoordinated in different parts of the government and scattered universities; both wanted a central funding agency that would encompass military and civilian research, would foster education and disseminate science throughout the country, and would assess and coordinate the research being done in the country's universities and institutes.[12] But the differences in their plans were philosophical more than they were administrative, and therefore fundamental. It was a debate about how science thrives and what

its relationship to society should be. Bush's plan was predicated on autonomy for scientists, aiming to provide them with independent leadership drawn from prominent universities and complete freedom of inquiry in choosing and pursuing their research queries. Kilgore, at heart a populist, advocated a system that would be more accountable to the larger society, with an agency governed by a committee consisting of ordinary citizens, labor leaders, and educators as well as scientists, and a director, not necessarily a scientist, appointed by the president. He wanted research to address directly the nation's social and economic needs, and he wanted funding deliberately distributed around the country. Patents from the research would belong to the public. In short, Kilgore wanted an agency closer to the political processes so that it could be guided by people's perceived needs, while Bush wanted an agency more expert-driven and insulated from the kind of public control that liberal political circles

ing has supported an astonishing explosion in our knowledge about every aspect of our universe, world, and human physiology, society, and psychology. To choose a few examples out of hundreds of thousands: Human traits, at first thought to be a straightforward expression of inherited parental DNA, have been shown to be influenced epigenetically by parental environment. Astrophysicists have observed colliding neutron stars creating the heavy elements we find on Earth. Macroscopic quantum entanglements have produced simultaneous changes in systems widely separated from each other. Gun violence has been characterized on epidemiological and psychological grounds. Geoscientists have explained how movements of tectonic plates carry biological carbon compounds and organisms deep into the Earth. Irrational economic behavior and human implicit biases are recognized, categorized, and predicted. Individual brain cell activity can be observed instantaneously

as creatures think and process stimuli. Emission and removal of carbon in the Earth's atmosphere is understood in detail. The public has had a vague notion of the creativity, beauty, and power of these advances and has wanted them to continue.

Yet the commitment to increasing federal funding—the large piece of the Bush implicit policy bargain—could not be sustained. From 1968 to 1971, as costs of the war in southeast Asia soared, federal research spending fell 10 percent (in inflation-adjusted dollars) with spending designated for basic research falling even more (by 18 percent from 1967 to 1975). Today federal spending for research and development (R&D) is less than 40 percent of what it was in the 1960s, as a percentage of the gross domestic product. Spending on R&D in industrial corporations has grown, keeping the overall spending at approximately 2.5 percent of gross domestic product (GDP) since 1968.[17] But as Bush had pointed

out, corporate funding is almost entirely short-term and developmental, supporting commercially predictable outputs benefiting the investing corporation, rather than innovative research that anyone could build on. Compared with many other countries, the US investment in scientific research, once an international benchmark, has not kept pace. At least seven other countries surpass the United States in public R&D funding as a percentage of domestic economy. Scientists, seeing federal funding, though large, as far less than optimal, continually lobby for more funding. There have been occasional spurts of support—for example, in connection with the space race and the Apollo program in the 1960s, the biomedical boom and doubling of the budget of the National Institutes of Health two decades ago, and the 2009 economic stimulus. It remains to be seen whether recent proposals for increased R&D budgets, such as the conveniently named Endless Frontier bill, will be realized in the federal

appropriations process. In any case, although the federal funding of R&D is much less than could be spent productively, the post–Second World War commitment to funding of science changed the landscape for science permanently.

* * *

Nevertheless, there is reason to ask: Is science providing all it should, and are citizens receiving what they need from science? Bush wrote that scientific progress was essential in the war against disease and could improve public health—yet a thriving scientific enterprise has not prevented millions of people from putting their children at calculable risk by failing to get vaccinations. Nor has the scientific progress been enough to prepare the United States to deal with a major virus pandemic in 2020. And it has not resulted in the United States undertaking the corrective measures required to stem costly climate change.