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Reopening *The Endless Frontier*

An Essay by Melissa Flagg, PhD

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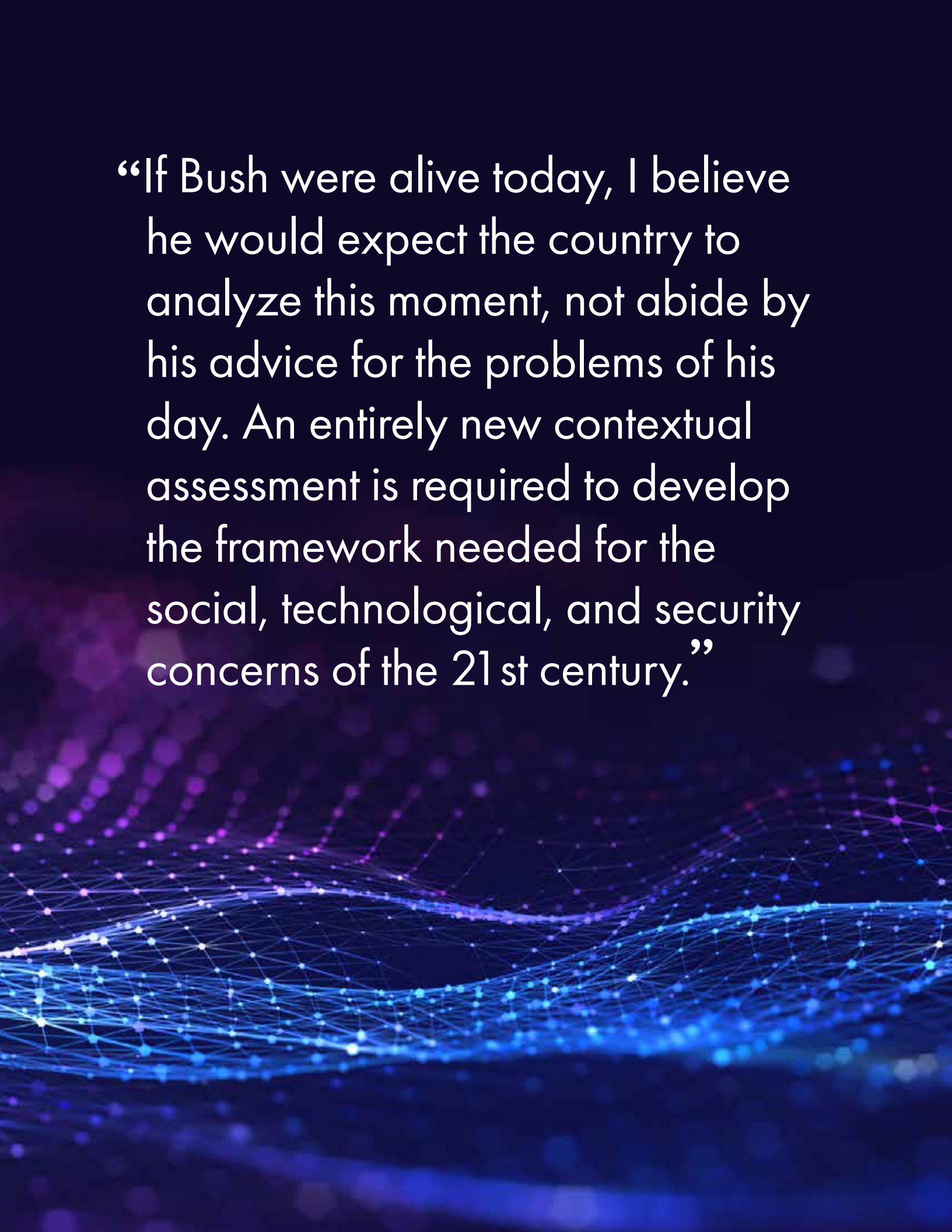

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Reopening *The Endless Frontier*

Vannevar Bush, photo credited to "OEM Defense," circa 1940-44, United States. Library of Congress, http://loc.gov/pictures/resource/cph.3a37339/

Vannevar Bush's *Science: The Endless Frontier* is best known for its call to establish sustained federal funding for basic research, especially within American universities, and for creating the National Science Foundation, America's first basic science funding agency. This short document is foundational for the modern American technological environment, so much so that people still quote it today. Although understanding history is critical, being held hostage by it is dangerous. The document provides incredible insights into an approach for critical thinking during a transition; however, many remain attached to the specific prescriptions he laid out for a set of problems that existed in 1945. Bush is fetishized in the scientific and political community, but few have taken the time to read his full document. Instead, they pick and choose snippets of what he wrote or, more commonly, repeat quotes they heard from others. Much of what people believe about Bush is at best a half-truth and at worst a nostalgic mythology.

The policy innovations that emerged from Bush's recommendations in 1945 have been very successful in many ways. His prescriptions were ideal for a post-WWII era America, and it is important that sustained funding for foundational science continues. Nevertheless, endlessly perpetuating solutions that were correct at the time does not follow Bush's true legacy, which was to analyze the current national context, specifically focusing on the U.S. science and technology (S&T) system, create a new institutional landscape that filled gaps in that system, and ultimately provide a global model for others. If Bush were alive today, I believe he would expect the country to analyze this moment, not abide by his advice for the problems of his day. An entirely new contextual assessment is required to develop the framework needed for the social, technological, and security concerns of the 21st century. Following his legacy begins with honestly confronting the contemporary context, as difficult as that may be.

***Endless Frontier* and Its Legacy**

Bush crafted his report during a moment of geopolitical transition. In 1945, Bush, the director of the Office of Scientific Research and Development, was asked by the president to examine lessons learned from his work during WWII and recommend how the U.S. could establish a solid scientific and technical foundation that did not depend on its now-devastated allies. The ensuing report articulated the characteristics of the postwar global and national context, the scientific resources of the time, and the big challenges the country faced: curing disease, securing the nation, and serving the public good.

Bush argued a strong scientific community and a pipeline of ideas and inventions were the keys to these priorities. But, unlike its allies—the previous leaders in global S&T—the United States lacked one component of their successful systems: a source of sustained scientific funding in its academic institutions that ensured a steady stream of talent and ideas. It was believed that the market and government would be able to access and build upon that talent pool and their ideas to solve concrete challenges in the nation. Thus, he recommended the federal government make a long-term commitment to fund research in aca-

demic institutions without the pressures of immediate profit or application. This was revolutionary in that it defined foundational (or later basic) research as a public good, a necessity for the health and security of the nation.

The report's recommendation for federal funding of basic research endures. The mechanisms and purposes of that funding, however, have expanded dramatically. American leaders have attributed an array of things to Bush that they have taken out of context or that he simply never said, especially as the value of basic science was challenged in the 1980s and 1990s. One deviation from his vision is the proliferation of funding agencies. Bush advocated creating one agency, the National Science Foundation, that would focus on patient, sustained funding at universities. This was ignored from the beginning, as the Department of Defense wanted its own institution and created the Office of Naval Research almost immediately. The United States now funds scientific research through an ever-expanding set of agencies that include the Department of Defense and the component services, NASA, the Department of Energy, the National Institutes of Health (and other HHS agencies), the Department of Homeland Security, the Department of Agriculture, the Department of Commerce (to include NIST and NOAA), the Environmental Protection Agency, and others.

Although the national dialogue invokes Bush as a prophet of the value of basic science, it has glossed over his original focus on mission. Bush called for patient funding for foundational science in order to solve problems, not for its own sake. Bush called out curing disease, national security, and the public welfare because these were specific challenges in 1945. Progress was finally being made with treatments, but infectious disease was still a major killer. A huge population of men was returning from the war unemployed. The nation needed innovations to ensure it could emerge stronger economically and socially after the war. The U.S. would have to provide its own world-class military and the technological foundations for that military in the future.

Bush never suggested these would remain the key problems for all time nor that his solutions would remain appropriate. They were merely the results of his analysis of the challenges that needed to be addressed in the economic and geopolitical moment of 1945 and the gaps that were present at that time. The traditional global scientific leaders—Germany, Britain, and France—were in ruins. The United States needed to be self-reliant and had a rare opportunity to rise in a vacuum of competition while employing Americans returning home from the largest war the world had ever seen.

Bush's method was to assess the landscape, identify the primary problems, and articulate a limited set of recommendations that the government was well suited to implement and that would help across the problem sets. By the end of World War II, American philanthropic and industrial research funding was trending down, and the government had no committed process or source of funding to support basic research. Bush knew the United States would not be able to depend on its allies for such knowledge, given the state of the world at the time, so this became a national security imperative. A steady current of ideas and inventions would have clear eco-

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nomic benefits as well. Thus, his key recommendation was that the government create a federal system for patient funding that leveraged America's growing academic institutions.

Bush emphasized his recommendations would not solve all the problems he delineated. Rather, they were feasible, targeted actions the federal government could take to fill systemic gaps that would have the greatest impact. He believed industry should also fund science and the government should also support mission agencies doing applied work, but patient funding for foundational research, especially at academic institutions, was missing from the ecosystem.

Moment of Geopolitical Transition

The gaps Bush saw 80 years ago are no longer present, either domestically or globally. For one thing, science, science funding, and scientists are not scarce. Science is no longer a bastion of a few wealthy, elite nations. A tremendous breadth of science is being conducted across many countries. Knowledge and infrastructure are widely disseminated, and global R&D investment has more than tripled since 2000 to about $2.2 to 2.4 trillion annually. The globalization of science has been matched by a geopolitical shift. The United States spends only a quarter of that global total. China has matched the American share of global R&D; the rest of the world contributes the other half. Talent is also widely disseminated. Conservative estimates of scientists and engineers with PhDs add up to around 20 million globally, but the relevant talent pool is larger and growing. The World Economic Forum estimated that in 2016 alone India had 2.6 million STEM graduates; China, 1.7 million; the U.S., 568,000; Russia, 561,000; Iran, 335,000; Indonesia, 206,000; and Japan, 195,000.

Domestically, the federalization of U.S. science peaked in the late 1960s, when the federal government provided roughly 70 percent of total American research and development (R&D) funding. Now, the federal government provides less than 20 percent of it. Federal funding has remained relatively flat, while industrial R&D investment has skyrocketed, and philanthropic funds and academic endowments have likewise followed an upward trend.

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Buried within this global increase in scientists and science funding is a shift in the incentive structure. The quality and success of basic science has come to be assessed by short-term measures like the quantity of publications in expert-focused technical journals and the number of times they are cited. In 2022 alone, estimates suggest there were over 2.8 million scientific publications. According to a study by Lutz Bornmann and Rüdiger Mutz published in Journal of the Association for Information Science and Technology in 2015, the rate of scientific publication has been growing exponentially. The growth rate, as they measure it, was 2–3% at the time just before Bush published his assessment; by 2010, it was 8–9% per year. This suggests a doubling of the entire scientific literature every 11–12 years. That is an enormous well of scientific output, largely published in highly specialized journals and communicated in opaque technical jargon.

This output measure of the amount of science may be valid, but it should not be mistaken for an outcome measure. Scientists produce papers, but they often do not see those ideas through to actual solutions. Publications are their measure of value within their technical community, and those publications are often used to make grant awards and promotion decisions. Even ostensibly patient funders demand quantifiable metrics to show immediate value, and a publish-or-perish culture dominates global science, especially in the U.S.

Another problem is that policymakers have become increasingly fixated on China. It is critical to resist the temptation to define national identity through the lens of an adversary. China's rise to parity with the United States has been steady over the last 30 years. This reality—that whether the world ever was unipolar, it is not now—has been jarring for American leadership. Often one does not realize such a transition is underway when it begins. One does not know the shape of the future until it arrives; fear of that uncertainty may drive the human tendency to cling to a past that is already gone or try to recover the old order.

I reject that, as I think Vannevar Bush would have. It is not helpful to keep reaching back to a past that simply cannot be re-created rather than proactively building a future based in the current reality. The United States will not be the global hegemon going forward, but that does not mean its adversaries should be allowed to define the future. America needs to define its own role, one in which its people thrive. Following Bush's approach and reopening the endless frontier requires preparing for a new future grounded in the reality of this moment.

What Would Vannevar Bush Do?

Bush argued a robust pipeline of new scientific knowledge was necessary if America were to be a secure, healthy, and economically vibrant nation: This foundational notion remains true today, but the pipeline is flowing freely. Funding and execution of basic science must be sustained, but other national needs and new gaps have developed over those intervening decades.

If Bush were here today, he would not advise simply pouring more funding into the same system created in 1945. He would advise using available resources to assess the current domestic situation within a changing global landscape, identify the most pressing problems, and discern gaps that have developed in the intervening 80 years. Although many federal programs support basic science on one end of the pipeline, and many others support the market and commercial endeavors on the other end, there are few incentives or structures to solve national problems in the absence of a market incentive. Patents languish where institutional innovators lack interest in developing commercial applications. The market is also not the full answer, as it has a short-term focus that cannot be counted upon to address national challenges. Consider antibiotic resistance: What company wants to invest in developing a drug with the goal of limiting its use? There is not enough sustainable support or new models for bringing people together to take research ideas from laboratory demonstrations to real-world solutions that simply will not make anyone rich.

America's R&D and innovation system has a significant and sustained flow of federal funds for academic research, and there is a deep well of scientific expertise both within and adjacent to the federal government. The government provides tax breaks for R&D, small business innovation research grants, and entrepreneurial training. Yet the current system lacks connective tissue between ideas, inventions, and innovations and the problems faced at local, state, and regional levels. There is little focus on helping

solve actual tactical problems across the nation that affect U.S. citizens every day but cannot easily be monetized. Westerners need solutions to water management, rural communities face the opioid crisis, and those near nuclear facilities worry about terrorism. There are not enough mechanisms and platforms through which communities with problems can help set the research agenda and expect capacity building and solutions to materialize. Taxpayers support this entire system, but they are rarely the focus of any serious discussion.

Everything about the global S&T landscape has changed, yet the U.S. is still talking about Vannevar Bush and his solutions to a 1945 set of problems—for example, the Senate version of the 2022 CHIPS and Science Act directly paid him homage. Bush's true contribution was not his policy prescriptions for science, it was how he assessed the past and present situation, identified areas of significant change that required new approaches and offered new opportunities, placed the challenges of his time within that context of change, and identified a small number of interventions likely to have the most crosscutting effect on the overall system.

The same basic approach is needed today. The United States is again at a moment of great change, but the global context, challenges, capabilities, and gaps are very different. This new landscape does not mean one must throw out the old, but it does mean America needs to accept that it is no longer 1945 and it never will be again. Only then can the 80-year-old insights of Vannevar Bush be applied in a way that will help the country thrive in a way that benefits everyone.

The Andrew W. Marshall Foundation

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