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A “SEDATIVE” *for Science Policy*

COVID-19 reveals the failures of a powerful metaphor.

If I have to read another article about Vannevar Bush I’m going to throw up. That is what a graduate student of mine told me last fall as we looked forward to a class unit on post-World War II science policy. I can sympathize. I have been writing about Vannevar Bush and his legacy in American science and technology policy for almost 30 years.

Science, the Endless Frontier, Bush’s famous 1945 report, continues to be revered in the science and technology policy community. For instance, in 2020, the 75th anniversary of the report, the National Academies of Sciences, Engineering, and Medicine convened a symposium celebrating the anniversary; President Trump’s science advisor used the report to frame his annual congressional testimony on federal research and development investments; and a bipartisan set of congressional representatives introduced major new legislation called the Endless Frontier Act, ostensibly carrying forward the Bush legacy.

If anti-nausea medication is still in order, perhaps one reason is that the themes that *Endless Frontier* discusses never seem to get resolved. The role of experts in a polity was explored in Plato’s *Republic*, and the discussions have continued in an unbroken line to this day. In that sense, Bush’s report can be viewed as simply a touchstone anchoring important debates about knowledge in policy, politics, and society. But in another and more important sense, Bush’s report, and specifically the metaphors and language it introduced into science policy discussions, has served to profoundly shape thinking and action on the role of science, scientists, and other experts in broader society.

The United States is in the midst of a historically catastrophic response to COVID-19 that should raise questions about Bush’s continuing influence on science policies. The central metaphor of the endless frontier draws on an influential, but severely dated and misleading conception of American history, which hides challenges and problems in the guise of idyllic imagery. It also supports a powerful argument about the separation of science from the rest of society, an arrangement that has

benefitted the scientific community, but in some instances has also contributed to limiting its contributions to societal benefit. The pandemic has created a valuable opportunity for reconsidering the social responsibility of leading scientists and scientific institutions in the context of the Bush legacy.

Dissonance at the heart of science policy

The United States’ response to Covid-19 has revealed the consequences of incompetency in the White House and in the failed leadership of federal agencies. The full scope and factors underlying this momentous policy failure will no doubt emerge in months and years to come. The chaos-ridden US approach to the pandemic has also revealed a fundamental dissonance at the heart of the nation’s science policy: it is possible to achieve spectacular scientific successes alongside outright social failures that science was supposed to prevent.

Richard Horton, the editor of the medical journal *The Lancet*, has called this “one of the strangest paradoxes of the whole pandemic.” Horton characterizes the dissonance: “No other country in the world has the concentration of scientific skill, technical knowledge and productive capacity possessed by the U.S. It is the world’s scientific superpower bar none. And yet this colossus of science utterly failed to bring its expertise successfully to bear on the policy and politics of the nation’s response.”

But the jarring disconnect between utter policy failure and scientific superpower status is not in fact a paradox. It is a design flaw, deriving at least partially from a science policy that has emphasized the separation of scientific achievement from societal outcome. Extracting science from its broader societal role is arguably the most significant intellectual influence of *Endless Frontier*.

Indeed, the essence of *Endless Frontier* was an extraordinary claim: that the economic, health, and military security of the nation depended on a rather modest investment in

university-based science that was carried out “without thought of practical ends.” The power of that claim persists to this day. For instance, in testimony before Congress in early 2020, Kelvin Droegemeier, the director of the White House Office of Science and Technology Policy and science advisor to President Trump, invoked *Endless Frontier* to explain how federal R&D investments leads to societal benefits: “The Federal government serves as a catalyst for innovation by investing in early stage basic and applied research, particularly in areas where little or no commercial incentive exists.” The result? “We have built the best discovery and innovation engine in history on bedrock American values, such as free inquiry, competition, and inclusion. And as Dr. Bush predicted, the rewards indeed have been great for our Nation and the world.”

The model of progress that Bush offered and Droegemeier echoed 75 years later puts science and scientists at the beginning of a process that leads from research investment to achievement of societal progress. From this perspective, the social responsibilities of science are unconnected to social outcomes of science. Securing scientific progress sets the process in motion. In this view, the more the government spends on science, the more social benefits must accrue.

This common reading of *Endless Frontier* has always been

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selective and superficial, however. In 1991, US Representative George Brown Jr. (D-CA), then chair of the House Committee on Science, Space, and Technology, and a skeptic of this interpretation, noted that *Endless Frontier*, “has often been invoked by the academic research community as an almost biblical command for robust, no-strings-attached federal support of scientific research.” Meanwhile, scientists and decision-makers have typically paid less attention to another observation made by Bush in *Endless Frontier*: “Science, by itself, provides no panacea for individual, social, and economic ills. It can be effective in the national welfare only as a member of a team, whether the conditions be peace or war.” Teamwork implies shared responsibility not only for team successes, but also for failures.

By helping to make science a principal priority of federal spending, *Endless Frontier* has undoubtedly contributed to the realization of many benefits for US and indeed global society. But at the same time, obvious disconnects between scientific achievements and related societal outcomes raise uncomfortable questions about the social responsibility of the scientific community, questions that have come to the fore in the era of COVID-19. Before returning to the pandemic, I want to explore the political symbolism of *Endless Frontier* and how it discourages asking questions about the social responsibility of the scientific enterprise.

The frontier as “vital force”

Within the field of science and technology policy, scholars have long understood that the lasting impact of *Endless Frontier* was not its policy proposals but its role in shifting how we think and speak about science, technology, and government. Bush’s choice of the “frontier” as the key metaphor for making his case mobilized a uniquely American concept that had gained widespread political and cultural currency following Frederick Jackson Turner’s influential 1893 essay, “The Significance of the Frontier in American History.”

In Turner’s telling, which has since been the focus of countless papers and dissertations among historians, the closing of the frontier in 1890 demarcated a significant point in American history: “Up to our own day American history has been in a large degree the history of the colonization of the Great West. The existence of an area of free land, its continuous recession, and the advance of American settlement westward, explain American development.” Turner’s western frontier was a source of national dynamism: “Behind institutions, behind constitutional forms and modifications, lie the vital forces that call these organs into life, and shape them to meet changing conditions.” When it closed, Turner argued, that dynamism was sapped.

It is hard to overstate the lasting significance that Turner’s

assessment had on US culture and politics. For instance, Theodore Roosevelt invoked the frontier metaphor at the start of the twentieth century to justify the violence of American football, which he argued was needed to provide men with dangerous experiences that were no longer available, in order for them to become more masculine. And in a 1934 speech to the Commonwealth Club in San Francisco, President Franklin Roosevelt lamented the closing of the western frontier and attributed some of the nation’s economic problems to it: “Our last frontier has long since been reached, and there is practically no more free land. More than half of our people do not live on the farms or on lands and cannot derive a living by cultivating their own property. There is no safety valve in the form of a Western prairie to which those thrown out of work by the Eastern economic machines can go for a new start.” As a consequence, “We are now providing a drab living for our own people.” Roosevelt thus invoked the closing of the frontier to justify government action to directly address the Great Depression.

For Vannevar Bush, the American frontier also provided a justification for government action. In his 1970 memoir, *Pieces of the Action*, Bush wrote, “I remember when I was told that the frontier had been occupied, that all of man’s wants had been met, that science had come to the end of a trail, that future growth would depend only on increase of population.” The closing of the frontier thus represented



Our triumph in the cosmos is our anthem to the Soviet Union!, 1950s-1960s.

an end of achievement for the American people.

Recognizing at the close of World War II that a case needed to be made for future government support of science, Bush drafted a letter for President Roosevelt to send to him, requesting that he—Bush—write a report laying out that case. The letter invoked the frontier metaphor: “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.” Bush then redeployed the metaphor in his report.

The rhetorical brilliance of using the frontier metaphor to argue for government funding of science was that it not only tapped into a powerful cultural current but also provided a ready-made counterargument to potential political opposition. As Bush noted: “It has been basic United States policy that Government should foster the opening of new frontiers. It opened the seas to clipper ships and furnished land for pioneers. Although these frontiers have more or less disappeared, the frontier of science remains. It is in keeping with the American tradition—one which has made the United States great—that new frontiers shall be made accessible for development by all American citizens.” The symbolism of “new frontiers” provided a historical justification for government

action while advancing the political interests of scientists seeking greater government funding and politicians seeking public support.

Science as an “Endless Frontier” thus countered concerns expressed by some politicians prior to World War II that scientific advances, especially in agriculture, led to poverty. For instance, in a March 1935 congressional hearing on the advancement of agriculture, Representative John R. Mitchell (D-TN) expressed skepticism about the wisdom of government support for agricultural research: “With the right hand, through our [agricultural] extension service, we are seeking to make 2 blades of grass grow where 1 grew formerly, and then, with the left hand we proceed with a [crop] reduction program.”

The undeniable achievements of science and technology in support of the war surely helped to assuage political concerns that funding more science could have a negative influence in the nation’s economy. If there were any lingering doubts about the impact of government investments in science, these were likely swept away when the United States dropped atomic bombs on Hiroshima and Nagasaki with an enormous human toll just two weeks after *Endless Frontier* was submitted to the president (now Harry Truman). Bush could invoke the role of science in helping to deliver victory in the war to sell to politicians a very different idea of science as the key to the nation’s future after the war.

The frontier as “sedative”

The western historian Patty Limerick, a colleague of mine at the University of Colorado Boulder, has written brilliantly on the pathological consequences of the frontier metaphor in the context of the US space program, a critique that applies equally well to its use in science policy. Limerick observes that, “the metaphor you choose guides your decisions—it makes some alternatives seem logical and necessary, while it makes other alternatives nearly invisible.” She explains that “the old frontier model”—the one articulated by Turner—“denied consequences and overruled failure.” Pursuing and occupying an empty frontier absolves the occupier of any responsibility or accountability for forest fires, destruction of Indigenous societies, alcoholism and unemployment on reservations, depleted groundwater and acid mine drainage, or other “consequences and instructive failures” of the “new, real Western history.”

Turner’s version of the frontier in describing and explaining the history of the American West eventually broke down when historians took a closer look at it in the context of a more self-critical era. Scholars such as Limerick found that it ignored and downplayed Native Americans, Hispanics, women, inequality, environmental degradation, and other important dimensions of the real West, not the imagined one. Limerick argued that the frontier metaphor served as a sort of “sedative” when it was applied uncritically to the US space program: “The space program needed a metaphor that would keep people alert, regularly examining their own behavior and their own thinking, and instead they got a metaphor with exactly the opposite properties—a metaphor that makes its own believers complacent, even smug, and inattentive to their own operating assumptions.” The consequences of a bad metaphor may always be debatable, yet the dominance of the frontier as a justification for human space flight helps to explain apparent complacency associated with the space program over the past 50 years. The Space Shuttle and Space Station programs, characterized as “next logical steps” on our journey to colonizing the space frontier, were both dead ends.

In science policy, the adoption of the frontier metaphor via *Endless Frontier* served to rationalize research exclusively on the basis of the motivation of the individual scientists, “dictated,” in Bush’s words, “by their curiosity for exploration of the unknown.” In so doing, the metaphor has been an intellectual soporific, absolving the scientific community from the need to consider its broader responsibilities. One of the most obvious side effects of this sedative are the many perverse incentives—well known and oft regretted—that have come to dominate the academic culture of science, which rewards scientists for how many papers they publish, how often those papers are cited, how much grant money they bring in, how many patents they file, and how many PhD students they advise, with little regard to the social value and impact of the work they do.

The invention of basic research

If Turner’s frontier had offered the open terrain into which America could “go for a new start,” Bush’s frontier offered the terrain that science could explore as a foundation for progress. To operationalize the metaphor, Bush chose the term “basic research” to describe what scientists who ventured into the frontier would be doing—in contrast to what Bush called “applied research,” which heretofore had been focused on specific, tangible agricultural outcomes.

In his 1970 memoir, Bush explained why he used the phrase “basic research” as a synonym for what had previously been called “fundamental research.” His thoughts on this are worth quoting in full:

“To persuade the Congress of these pragmatically inclined United States to establish a strong organization to support fundamental research would seem to be one of the minor miracles. We in this country have supported well those pioneers who have created new gadgetry for our use or our amusement. But we have not had during our formative years the respect for scientific endeavors, for scholarship generally, to the extent it had been present in Europe. There were some on Capitol Hill who felt that the real need of the postwar effort would be support of inventors and gadgeteers, and to whom science meant just that. When talking matters over with some of these, it was well to avoid the word fundamental and to use basic instead. For it was easy to make clear that the work of scientists for two generations, work that had been regarded by many as interesting but hardly of real impact on a practical existence, had been basic to the production of a bomb that had ended a war.”

With hindsight, it is clear that Bush’s semiotic wizardry worked simultaneously to satisfy two different types of participants in science policy discussions. For policy-makers the emphasis of the phrase is on research being *basic* to the achievement of political and societal objectives such as national security, jobs, economic growth, and health. For scientists, the emphasis is on *research* that “is performed without thought of practical ends”—what prior to Bush was typically called “pure research.”

Thus, one of the complex legacies of *Endless Frontier* is that the language it introduced serves contradictory purposes. This can create challenges for both communication and action as policy-makers and scientists can use the same words but mean very different things.

Bush’s conception of basic research made superfluous detailed justifications of federal government investments in research. His argument had been anticipated by Harvard University’s Arthur Kennelly, who explained in the journal *Science* in 1926 that basic research “made without any suspicion of applicability” meant that “useless scientific knowledge is now a contradiction in terms.” Bush’s report expanded on and made broadly accessible that perspective, which has carried forward to the present.

In his 2020 testimony to Congress, White House science advisor Droegeheimer asserted a similar grand claim, “R&D

represents the seed corn of innovation, and thus of our economic prosperity, quality of life, and national security.” Science, in other words, is thus responsible for many positive societal outcomes. Droegemeier made no mention of less positive outcomes in areas directly by science, technology, and medicine, such as in health, environment, or economic inequality. A legacy of the influence of *Endless Frontier* is that we typically give science credit for the positive but assign no responsibility for the negative, in contradiction to Bush’s less-honored assertion that science achieves its outcomes not by itself, but as part of a team.

In Bush’s foundational mythology of science policy, all research is useful or potentially useful. Because we cannot know what research will ultimately prove useful, the most effective science policy emphasizes expanding investment in research across the board. As Bush wrote in *Endless Frontier*, “Statistically it is certain that important and highly useful discoveries will result from some fraction of the undertakings in basic science; but the results of any one particular investigation cannot be predicted with accuracy.” It then follows that the best science policy is one that supports broad investment across all science.

The mission of basic research

In 2020, about half of the government’s \$90 billion investment in research was classified as “basic” by the Office of Management and Budget. Given that the vast majority of federal R&D goes to so-called mission agencies, with science employed as a means, not as an end, the actual meaning of this classification is anybody’s guess. It attests, however, to the continuing influence of the *Endless Frontier* vision on the way that science policy is imagined and portrayed by decision-makers and scientists alike. One result is a papering over of the question of social purpose: because basic research is supposedly carried out “without thought of practical ends,” the only policy variable that matters is how much money gets spent. But this doesn’t help policy-makers or the public understand how, and how well, science is able to contribute to societal objectives. This is hardly a new observation. In 1965, Alvin Weinberg, then the director of the Oak Ridge National Laboratory and an important voice in postwar science policy, argued that looking at a total federal R&D budget was “misleading,” and observed that “we do not argue about how much the government spends for transportation as a whole, or accounting as a whole, or legal advice as a whole.” But if, as *Endless Frontier* explained, basic science “as a whole” would potentially contribute to social goals, the only thing that matters is how much is spent.

Yet under the realpolitik of US science policy, societal and economic outcomes are the primary motivation for most federal research support, even in the National Science Foundation. The contradiction at the heart of *Endless Frontier* between no-strings-attached science and promises of social benefit can be seen in the recent bipartisan legislation to increase funding for NSF, and to change its focus as well. The

Endless Frontiers Act continues to put Bush’s metaphor at the center of science policy even as the bill would transform the National Science Foundation into the National Science and Technology Foundation.

The legislation prioritizes 10 technology “focus areas,” such as artificial intelligence, quantum computing, biotechnology, and materials science. Although one could debate the contents of such a list, the essential point here is that it is far from the prioritization of scientist-led basic research pursued with no consideration of application found in *Endless Frontier*. In fact, the proposed legislation subsumes the scientific work of the newly envisioned NSTF to achieving the goals of technology development in support of national goals. Yet the scientific work, explained in terms that Bush might have used, would be “to pursue basic questions about natural and physical phenomena that could enable advances in the key technology focus areas.”

This is mission science akin to the “basic work” of the US Department of Agriculture in the 1920s. In *Endless Frontier*, Bush recognized the political reality of the primacy of mission

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science: “Most research conducted within governmental laboratories is of an applied nature. This has always been true and is likely to remain so.” Setting aside the fact that there are already other federal agencies with missions focused on energy, disaster prevention, and so on, the clear message being sent by the proposed new legislation is that science has a responsibility in the pursuit of social outcomes.

John Marburger, science advisor to President George W. Bush, recognized in 2005 that science policy-making involves choices: “The question is not whether R&D investments are important, but what investment strategies are most effective in the rapidly changing global environment for science.” Asking and answering this question necessarily involves responsibility and accountability for outcomes, including both successes and failures. Yet when scientists are exploring the endless frontier “without thought of practical ends,” considerations of responsibility and accountability are unnecessary. The consequences of this incoherence may now have come home to roost in the pandemic.

The benefits of teamwork

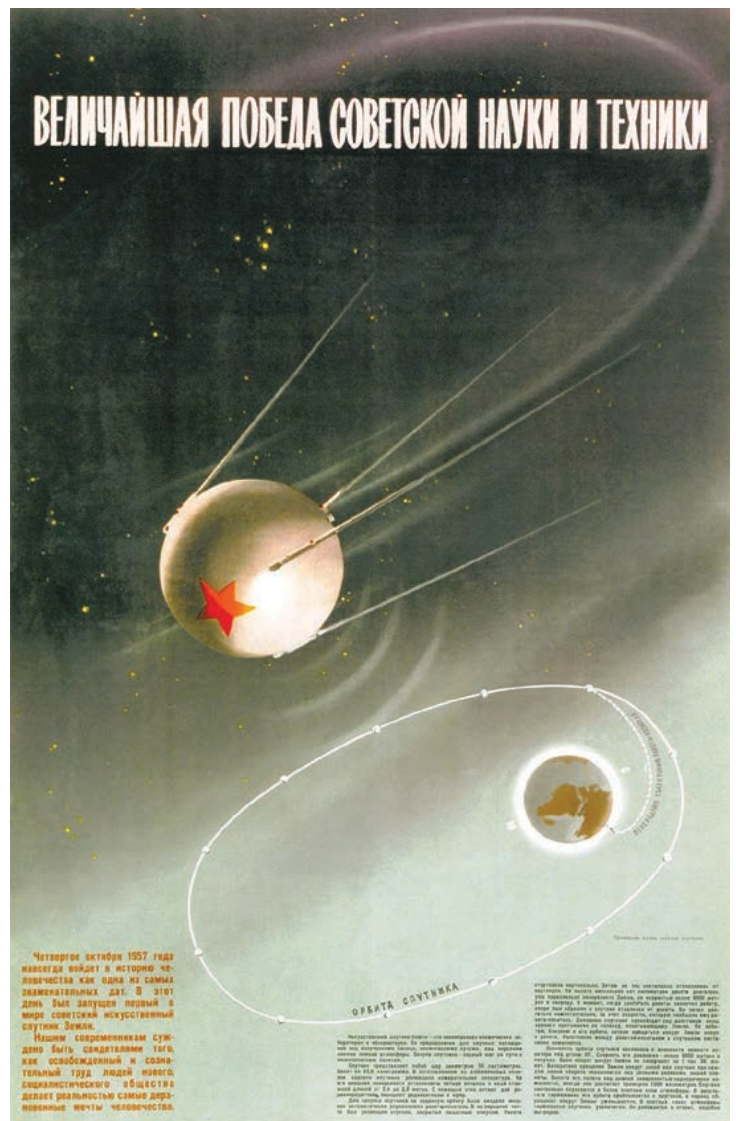
The complex legacy of *Endless Frontier* can be seen in an incredibly varied combination of scientific and societal outcomes in the 75 years since it was published. Some elements of the

federal government’s R&D enterprise, such as weather forecasting and agricultural science, have contributed demonstrably to a broad swath of improved societal outcomes. Such outcomes have resulted not simply because science and technology have advanced, but because many institutions in the public and private sectors have worked together as a team to integrate science with effective decision-making, in broader institutional, social, and political settings. For example, research on weather forecasts has resulted in scientific findings that have been combined effectively in public and private institutions with sophisticated strategies for communicating uncertain information (just look at your weather app), with emergency preparedness and response policies and practices, with building codes, land use planning, civil engineering, insurance programs, and so on, to deliver significant value across many social and economic activities.

But some outcomes are less uniformly positive—as in health care and employment opportunity (both of which were central focuses for *Endless Frontier*)—even when scientific and technological advances have been as notable in quality or volume as for weather or agriculture. The disparate outcomes related to science and technology investments underscore that the achievement of societal objectives does not arise organically from public investments in science and technology, nor can the fruits of those investments be adequately measured in terms of scientific achievement. They require, as *Endless Frontier* warned, teamwork. And successful teamwork means shared responsibility and accountability.

In 2020, the need to ask uncomfortable questions about the social responsibilities of the scientific community are more important than ever. Consider that over the past several decades top US research universities have become less accessible to Black and Hispanic students. Meanwhile, federal R&D funding for US universities increased by 85% (in constant dollars) over the two decades ending 2017. Life expectancy at birth in the United States hit its high point of 78.9 years in 2014 and has declined overall since then. Yet over that same period, federal spending for health R&D increased by about 14%. In recent years, the nation’s electorate overall has seen an increasing degree of political polarization on key issues such as climate change and health care, despite the billions spent on research in these areas.

In exchange for generous federal support—“nearly uninterrupted growth,” in the words of presidential science advisor Droegemeier earlier this year—the scientific community is expected to provide “great rewards,” in the words of Bush in 1945, and repeated verbatim by Droegemeier in 2020. But the broader dissonance is increasingly difficult to ignore: the scientific community is doing quite well, but related societal indicators show fundamental problems in American society in those areas directly related to the promise of publicly supported science and technology. The extraordinarily poor management of



The greatest triumph of Soviet science and technology, 1957. In 1957, the Soviet Union was the first country to launch a satellite into space. Sputnik 1 and its elliptical orbit are depicted here.

the COVID-19 pandemic is both a lens on and an amplifier of the economic, health, educational, and other inequities so prominent in American society, despite all the promise and progress of science.

The symbolic legacy of *Endless Frontier* supports the view that the scientific community bears little or no responsibility or accountability for societal outcomes. After all, the scientific establishment is not responsible for policy-making and has direct control only on the results of research, not how they are applied or used. From this perspective the proper metrics for evaluating the contributions of science to society would

not be societal outcomes, but scientific productivity such as publications, patents, and Nobel Prizes. If this is your view, then you have likely been influenced by an interpretation of *Endless Frontier* that supports a necessarily weak connection between public investments in research and development, and any social responsibility and accountability for broader societal outcomes related to those investments.

American science and the COVID-19 disaster

There is no doubt that the mind-boggling incompetence of the Trump administration has led to the catastrophic US response to COVID-19. But this failure does not absolve the scientific community from responsibility. Indeed, a wide variety of responses to the pandemic by the scientific community reveal that evading or embracing responsibility and accountability are choices that the community can exercise at different scales and in different settings.

Given the lack of political leadership, why hasn't national leadership of the scientific community—which proudly asserts its autonomy and independence in other matters—mobilized to provide independent and reliable information and guidance at the national level about COVID? One consequence of a lack of clear national guidance on topics such as the wearing of masks, the efficacy of hydroxychloroquine, and procedures for opening universities has been the creation of a mishmash of advisory bodies at the state, city, county, school district, university, and other levels to provide such guidance.

Participants in such bodies are no doubt well-meaning and embody high levels of expertise, but inevitably they have provided conflicting and inconsistent advice to citizens and policy-makers across the nation. For instance, on the question of whether it is safe to play college football, scientific and medical advisory bodies for different athletics conferences provided diametrically opposed guidance, based on the same available science. As we are continuing to learn (and as public health experts have known for decades), dealing effectively with a pandemic requires a considerable degree of national-level policy and coordination.

At the same time, the response of thousands of scientists across the public and private research enterprises has been impressive. Researchers from universities, research institutes, think tanks, and corporations have risen to the challenge of investing in R&D related to COVID-19. For instance, according to the Clinical Informatics Research Unit at the University of Southampton, the United States is the leading funder of COVID-related research. Yet sufficient money for science has never really been the problem in the United States. Of greater interest and importance are developments at a much smaller scale.

For example, as the pandemic spread across the country, researchers at my university quickly responded to a request by the Colorado governor to participate in a science advisory

group, created a research consortium, and engaged in rapid, collaborative research on topics as varied as vaccine development and aerosol transmission. These types of actions have occurred in hundreds of universities nationwide, many of which are working with local communities, public health organizations, governments, and private firms to serve not only their faculty, staff, and students but also surrounding communities. On my campus, researchers who previously did not work on public health have contributed to fundamentally new understandings of how viruses may transmit through aerosols. It turns out that working as part of a team to address directly a societal problem does not impede scientific discovery and may actually foster it.

Perhaps, then, as the COVID crisis demonstrates how scientific progress can go hand-in-hand with political dysfunction and societal disruption, it is also awakening university scientists from 75 years of sedation encouraged by the endless frontier metaphor. In the face of suffering and crisis, perhaps a new model of the social responsibilities of science and scientists can emerge, marked by a willingness to view leadership, success, and progress not merely in terms of scientific productivity but of social value as well.

Beyond COVID-19, this may often require new types of partnerships and collaborations to help ensure that scientific agendas are well matched with the needs and capabilities of other members of the teams that turn new knowledge into social value. To do so, the central metaphor of post-World War II science policy has to be abandoned. We scientists need to understand ourselves not as individual explorers freely colonizing an empty frontier, but as members of a team that goes well beyond science. As such, we need to up our game and share in responsibility for both wins and losses.

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