War on All Fronts

A Theory of Health Security Justice

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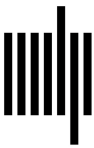

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Epilogue: Emergency Innovation

This book provides a basic account of just health security, a framework for public health ethics that is in parts derived from a common basis, and in others is inspired by the methodological strategies adopted by military ethics. In the main, this has focused on the arc of decisions that follow preceding, initiating, acting within, and ending a public health emergency: this mirrors the core of just war theory. But there is more to public health ethics, and more to military ethics, than just that. While an extension of these concepts is reserved for future work, one issue became particularly salient during the COVID-19 pandemic: the development and deployment of novel technologies in the service of pandemic response.

If there's one thing people love, it is new toys. And the promise of new technologies is, for most I have encountered in eight years living and working in the US, a vibrant one. There is acknowledgement of risk, but the potential rewards of technologies—as long as Americans possess them first[1]—are always first in their minds. There's a reason why a number of works in and around health security use the phrase "promise and peril,"[2] and, I think, a reason why promise and peril are ordered the way they are.

In the context of communicable disease, technology can absolutely be an asset. The Salk vaccine for polio, smallpox inoculations, and the development of the polymerase chain reaction method to replicate DNA have all been hugely beneficial in the prevention and detection of disease. While antibiotics face an uncertain future,[3] their presence in medicine over the last century has revolutionized everything from common infections to organ transplants, and even in viral epidemics have staved off secondary bacterial infections that may capitalize on and ultimately be the source of a patient's death.

But not all technologies are penicillin: in fact, almost nothing *but* penicillin is like penicillin. Moreover, the benefits of public health are not strictly

works of technology. Technology is wonderful, but its application is neither straightforward nor obvious.[4] Jason Schwartz, a vaccine expert at Yale University, is fond of saying that vaccines don't count; vaccinations count.[5] And vaccinations are ultimately very different from vaccines, so different that health security spends comparatively little time even conceiving of the former as technology.

But technology it is, and the connection between basic science and its ultimate implementation is sharpest when pressed into an emergent context. And nowhere, I think, is the war metaphor more heavily used—with the exception of the "warriors on the front lines," perhaps—in public health than when considering innovation during emergencies. In COVID-19 especially, the strategy of the United States writ large has boiled down to waiting for a sufficient number of vaccines to be discovered, authorized for emergency use, and then manufactured and distributed at a scale large enough to vaccinate the population. Even early reports discussed in chapter 7 were not much more optimistic—measures to increase social distance were only a means to endure until the availability of a vaccine.

Consortiums to produce these innovations took on militaristic names: the Israeli "COVID Moonshot" to design protease inhibitors takes its name from the overtly militaristic space race and was echoed in 2021 by the Bipartisan Commission on Biodefense's "Apollo Program for Biodefense"[6]—a Commission chaired by former senator Joe Lieberman, who killed the public option for the Affordable Care Act[7] that would have almost certainly made responding to COVID-19 easier. The Trump Administration's Operation Warp Speed which, while reminiscent of *Star Trek*, was arguably militarized through the lens of that same administration erecting the US Space Force as a branch of the US DOD. Most obviously, a *Wall Street Journal* article described a group of scientists and venture capitalists coordinated by Tom Cahill as pushing a "Manhattan Project" for COVID-19.[8] This last term was mirrored by a memorandum from Peter Navarro, then in the Trump White House, in 2020 describing a "'Manhattan Project' Vaccine Development."[9]

Despite this rhetoric, the connection between military, much less *wartime* innovation and pandemic innovation is tenuous. The aphorism is that "necessity is the mother of innovation," and what could be of greater necessity than defense of the nation? Examples like radar, the atomic bomb, air power, and codebreaking will come to mind as radical innovations completed inside armed conflict. But military innovation *in war* is

not as common as these images evoke; their circumstances are much less straightforward than rhetoric suggests.

Typically, bioethics and technology interact most in the context of (1) the ethical, legal, and social implications of technology, and (2) the ethics of particular research protocols used to conduct clinic research during health emergencies. This is a well-trodden path.[10] Rather, what we should do is—as increasingly happens in military ethics—consider the ethics of the institution of biomedical research as it pertains to pandemics.[11]

In this epilogue, I make inroads into just that. I begin with an examination of the two major submetaphors to describe the connection between military and health innovation: the moonshot, and the Manhattan Project. I then examine the current state of play in biomedicine in the US, and worldwide, in preparing for and responding to health emergencies, and how this features into larger norms around health security. I argue that the current metaphors and models of innovation are not just misleading but misplace priorities in pandemic preparedness in a way that privileges interests and preferences other than the justified aims of the public health state.

I then turn to a separate framing of technology in emergencies I dub the "Kalashnikov approach." This draws from the thinking of the Russian technologist and engineer Mikhael Kalashnikov and the rifle that bears his name. It draws from the features of the Russian experience in World War II—a closer analogue to the "block by block" experience of pandemic response in much of the world—and draws lessons, and warnings, from military innovation. It reprioritizes basic innovation and high returns on investment and access over more complex and risky intra-conflict innovation which, while perhaps sometimes permissible, exists like the rest of health security in a climate of neglect of basic social institutions. I conclude with how this might inform future pandemic response.

Moonshots and Manhattan Projects

The moonshot and the Manhattan Project are often invoked in reference to securitized scientific endeavor. The earliest reflection I can find in relation to contemporary biological science comes from Robert Carlson in 2003, and is comparative: Carlson prefers the Apollo Project, which "took place in the public eye, with failures plainly written in smoke and debris in the sky," to the Manhattan Project, which "took place behind barbed wire and was

so secret that very few people within the US government and military knew of its existence."[12] Carlson has called for a similarly broad, open vision, in 2000 writing an "Open-Source Biology Letter" to DARPA (paradoxically, part of the US DOD and infamous for a lack of transparency)[13] urging the funding of a revolution in biological technologies.[14]

In 2005, Senate Majority Leader Bill Frist, at a talk at the Nantucket Anthem, spoke about a "Manhattan Project for the 21st Century."[15] It is likely this was strategic: the year before, Republican lawmakers had introduced and passed the Project Bioshield Act first in the Senate, to amend the Public Health Service Act and allocate funds to improve medical countermeasures against diseases that might be used in biological terrorism. This was repeated in 2007 by Michael Osterholm at the University of Minnesota, who with Nicholas Kelley advocated for a Manhattan Project for a universal influenza vaccine.[16]

Today, the metaphor is obviously still alive and well, between COVID-19 Manhattan Projects and cancer moonshots, to describe great and usually expensive undertakings that purport to develop incredible new "game changing" technologies in different arenas. But this framing misses critical elements of each story, its form, and the norms that guided these projects. To begin with the moonshot, most commentators portray the space race as a singular goal to which the US was committed, almost a harkening back to a golden age of American science. But the project was anything but: it was rife with political tension from a Congress that lacked a consensus vision over the value and goals of space exploration, and a tension between the US DOD and NASA over the role of rocketry and its relation to national defense. The moonshot was complicated, and exceedingly messy. The fluctuations in political will and funding would ultimately lead to events like the Challenger disaster, and a complex legacy that has in it everything from increasingly dangerous externalities such as "space trash" to the increasing privatization and militarization of space.[17]

The Manhattan Project, on the other hand, arguably did not suffer from its secrecy. Rather, it was an experiment in scientific governance guided in part by the US military, but also with the enthusiastic participation of the scientists involved. Part of the formation of this project was to give scientists the room to experiment and direct research in line with a very concrete goal of developing a functioning nuclear weapon. But within that, the teams that formed the Manhattan Project—and especially the iconic Los Alamos site—were quite flexible and free with their design. The paradigm of this was Seth

Neddermeyer, allowed to pursue a seeming pipe dream of an implosion-style device involving plutonium, which required him to invent simultaneous detonators and shock physics in the process.[18] Secrecy was, it turns out, not an essential feature of the Manhattan Project *as a scientific project*, though certain aspects of its design as a project were responses to its secrecy.[19]

More importantly, neither the moonshot nor the Manhattan Project were decisive in solving an acute crisis. The Manhattan Project was arguably a response to an urgent situation, namely the threat of a Nazi nuclear weapon (and Japanese attempt at the same). But it outlived those projects, and moreover the architects of the project knew this and continued the project regardless.[20] It is also highly unlikely that the Manhattan Project ended the war in the Pacific, although it was arguably what led to an *unconditional* surrender. The moonshot existed outside of an armed conflict, and while competitive in nature was not pursued under emergent conditions like those of a conventional war. The Manhattan Project took seven years; the Saturn rocket family, eleven years to come to maturity. Both are also deserving of their criticisms, from Eileen Welsome's exhaustive documentation of the human radiation experiments that outlived the Manhattan Project,[21] to Gill Scott-Heron's *Whitey on the Moon*.[22]

The Risks of Emergency Innovation

With this in mind, technology during pandemics is something of a mixed bag. While there are hundreds of drug and vaccine candidates either authorized for use or under investigation in the ongoing COVID pandemic, persistent ongoing issues remain. The first of these is the approval process, and concerns about how truncated such a process can or ought to be to ensure a reasonable expectation of benefit on a population level, while managing potential risks such as serious adverse events.[23] Some suggested solutions, like human infection challenge trials, may cut down on discovery and approval time, but in the process jeopardize the already fragile relationships of trust between the publics—plural, as the public is not a monolith—and the public health-science-governance arrangement of the state.[24] Still other institutional levers such as the Emergency Use Authorization at the US FDA, reformed in the wake of the 2001 anthrax attacks, are potential avenues for rapid approval of drugs but pose risks both medically and reputationally, to providers and governments.[25]

Antivirals and other treatments are in a similar bag. The controversy and spectacle over hydroxychloroquine, which took up roughly 200 clinical trials over the course of 2020 but showed no benefit, was based on a poor set of assertions by French physicians from the outset.[26] The trial of remdesivir, originally designed to treat Ebola virus disease, was stopped by the NIH despite not showing statistically significant survival benefits for patients, but because it met an alternate endpoint of reducing the number of days in hospital for patients that did survive: a controversial decision about what counts in pandemic research.[27]

A flurry of digital contact tracing applications arose in 2020 in response to pressures to reopen the United States, among other jurisdictions. Some of these showed the potential for promise but unlike pharmaceuticals, the majority of these health applications were not subject to rigorous trial designs relative to other nonpharmaceutical public health interventions. This is a serious problem, and for digital contact tracing as part of the larger "big data" movement in public health. Sean McDonald, in 2016, noted that in bringing digital tools into disasters, groups often underestimate the practical and legal implications of digital systems, from data security to operational coordination in the fairness of algorithms.[28] Big data research has been the subject of considerable ethical analysis and demonstrated a need for robust oversight and trials, but in the context of COVID this was lacking.[29]

All of these have exacerbated the mistrust of public health, of science, and of government. This is not the fault, or at least not exclusively the fault, of science and scientists. But as with the impersonal account of disease, we need not issue blame to acknowledge the way that systems are built can be subject to normative critique. And here, there are serious structural issues.

Norms in Need of Change

A key issue for biomedical research is a lack of coordination and prioritization. This is important from the perspective of health security, which has largely regarded the chaos of the life sciences as a benefit.[30] For both these problems, part is internal to the governance of science; part is in virtue of the broader public health landscape.

The internal mechanics of science are disputed, but one popular account goes like this. Scientists publish papers based on two things: the significance

of the finding, and its priority. Less interesting findings—by the norms of the field—are worth less; being first is worth much more than being anything else and depending on who you talk to may be the only position worth having. Much of this in contemporary science is backed up first by modern journal culture, and second by the attention media increasingly pays to science during a public health crisis. In this environment, a number of strategies are possible, but two that are common are "followers" and "mavericks." Followers occupy existing epistemic trends and push them forward, where mavericks go in the opposite direction. It has been argued persuasively that both are useful in some degree to the progress of science.[31]

This makes for a series of important dynamics, however, that can become maladaptive in crises. The first is a potential for bandwagoning. We see this with the rapid pursuit of hydroxychloroquine trials over other alternatives; masses of scientists moving toward a single perceived epistemic highpoint that is important both by the norms of the field and society, and while demonstrated to be false consumed excessive scientific resources and was muddied by dozens of poorly constructed studies.[32] Even attempts to synthesize information through reviews have been further frustrated by a paucity of high-quality data, even among published studies, as groups rushed in to compute and then publish their work.[33] Bandwagoning occurs when the prospect of being interesting vastly outweighs the problem of not being first, and there is a prospect of achieving some level of recognition even as a second or third mover. Here, it no longer is rational to pursue untried methods if the tried method produces a result that will always lead to the satisfaction of scientists' instrumental goals. This is not a slight against scientists, moreover: they may still have some pure epistemic goals but shaped in the moment of crisis by other concerns or undermined by the sheer magnitude of a particular prospect.

The second issue is a lack of correspondence between pre-pandemic and intra-pandemic work. A common thread in the ongoing pandemic is a disjunct between priorities in research during not just the COVID-19 pandemic but across many major sources of potential emerging infectious diseases. The issue that arises is how to ensure funding for major infectious disease threats that incorporates a commitment to basic understanding of the diseases themselves. Coronavirus research, famously, has occurred in boom-and-bust cycles around major outbreaks, but with almost no investment in between, despite the warning of SARS.[34]

The third and final issue is what Jason Schwartz has called the turn to the "biomedical model" of public health. This model privileges medical countermeasures and vaccines as the ultimate solution to infectious disease. While eradication of endemic diseases is certainly only achievable through vaccines, or at least has been, the broader collection of public health interventions have not been biomedical in origin.[35] There has been significant investment in basic virology since 2001 to combat particular pathogens thought to be high risk, but never has such an effort been made to understand, trial, and optimize basic public health.[36]

What results is a series of high-investment, low-return trade-offs in many developed nations. The United States and United Kingdom combined have produced the largest number and some of the most promising vaccine candidates for COVID-19. In the background, their health systems are burning up, running out of supplies, and running out of people. Their public health interventions have failed to contain the viruses but not obviously for reasons beyond their control. Pandemic preparedness has made bad investments, focusing on high technology over logistics, planning, and politics; where technology is concerned, neither blue-sky thinking nor ground-level pragmatic concerns have been addressed. The military analogy here is a department of defense with stealth bombers but no pilots; with bullets but no riflemen.

This coordination problem, moreover, is seen in the ways health security research and practice arranges its recommendations. A common point of inflection with military and health innovation is in the infamous "wargame," a combination of physical, virtual, and table-top exercises designed to test theories and innovations against adversaries. These wargames are produced by both government and non-governmental actors and have been conducted on both bioterror incidents[37] and emerging disease pandemics.[38]

What is peculiar about these is the priorities they place on certain forms of innovation and strategy over others. First, recent wargames have emphasized the need for radical medical countermeasures (MCMs) as their highest or near-highest priority: the "Clade X" game run in 2018 made this its first priority; the 2019 "Event 201," unfortunately timed in November 2019 and simulating a coronavirus outbreak, placed it second. The latter of these, moreover, placed overriding emphasis on so-called public-private partnerships, beginning its recommendations with

> The next severe pandemic will not only cause great illness and loss of life but could also trigger major cascading economic and societal consequences that could contribute greatly to global impact and suffering. Efforts to prevent such consequences or respond to them as they unfold will require unprecedented levels of collaboration between governments, international organizations, and the private sector. There have been important efforts to engage the private sector in epidemic and outbreak preparedness at the national or regional level. However, there are major unmet global vulnerabilities and international system challenges posed by pandemics that will require new robust forms of public-private cooperation to address.[39]

What are less discussed in these more recent wargames are measures that have been well established as simple but effective means to reduce the burden of infectious disease—including pandemic disease. That is, healthcare access, widely available personal protective equipment, hospital staffing and financing, urban design, workplace access and decontamination, burials, and more: all issues that have been demonstrated as central to infectious disease elsewhere but are largely ignored by wargames of this kind. Event 201 in their recommendations, for example, recommend access to personal protective equipment, but only for transportation workers as part of their third recommendation to maintain trade in a pandemic.

The most charitable explanation of this phenomenon is that these exercises are often model systems that seek to understand a restricted but important part of the pandemic landscape. Event 201 could be interpreted as primarily an exercise in developing issues around public-private relationships. That is, its lack of attention to structural factors is indeed by design, but in the same way a researcher asks one question but not another. The TOPOFF exercise of 2001, for example, did include more detail on personal protective equipment, for example, so not all these exercises are absent these broader questions.[40]

A less charitable, but I suspect more accurate assessment would be that structural factors are messy, hard to model using means that appeal to scientifically minded researchers, and are unfortunately increasingly partisan ideas in American politics—and, indeed, those of many other nations. Moreover, such an assessment would make the wargame itself less charitable, and thus a more bitter pill to swallow for players who are behind the levers of power. Here, the choice is different: still a choice, but based in particular normative commitments that, over the course of this book, I have outlined as central to contemporary health security.

In either case, the choices are a problem. If the latter, it means that an important tool for policymakers is designed around ends that don't comport with the stated aims of public health—preventing, responding to, and ending pandemics. Rather, they are designed to appeal to a particular view of the world and demonstrate a minimal, politically expedient lift for policymakers. All that is needed is more funding for scientific research; all that is needed is for the private sector to be robust enough to replace the public sector (which we acknowledge is underwhelming, but provide no account of *why*, or how, that might change).

This has an analogy in military wargaming. In 2002, the Millennium Challenge was a comprehensive war game designed to test deployment of US forces in the Middle East and was if not explicitly, then implicitly a planning scenario for an invasion of Iran. The team playing opposite the US forces staged incredible initial victories by using low-tech solutions in an early strike on the US Navy and developing prosaic countermeasures to high technology such as using motorcycle couriers that could not be intercepted by aerial surveillance. The challenge was ultimately reconfigured by its designers to *force* a US win, viewed by the leader of the opposition team as a corruption of its initial intent.[41]

In the same vein, recent wargames have a view of pandemic response that encourages one particular normative view of health security but is vulnerable to the ground realities of an actual health crisis. Coverage of health security wargames has noted that the central thing they all held, seemingly mistakenly, was the US doing better than other nations in its response: a belief that seems false in 2021.[42] This is a clue to the possibility that these wargames are designed not to discover what we should do and why, but to enforce a particular version of "why" through the story they tell.

Even the more charitable view, however, is alarming. Writing in 2019, Ronald Klain, once "Ebola Czar" and now White House Chief of Staff, said of Event 201 and Clade X:

> I have growing doubts about these glitzy role-playing events. They create an illusion of improving preparedness, but do they? What ACTUAL progress has been made since the Clade X exercise? People/institutions should be play acting less, engaging policy makers more.[43]

There's an open question that remains about the plethora of wargames that have emerged: even if they accurately simulate a particular interaction in pandemic preparedness, why choose these elements—and what comes of

this? Vaccine development during COVID has indeed been rapid, at least for the first few candidates. But under that lies a lack of personal protective equipment, test kits and reagents, surgical gowns, oxygen, and even nurses.[44] Klain's comment drives at a central problem of the previous chapter: that the issues facing health security might be less about the policies or data available, and more about the norms health security itself embodies. This, I suspect, goes for science and innovation as much as it does everything else.

The Kalashnikov Model for Pandemic Innovation

Manhattan projects and Apollo programs are great, but they are grand challenges for great powers. Infectious disease, as health security practitioners love to tell us, is adept at bringing low entire civilizations. It is a faceless, invisible enemy, and the battle for a country is fought in every home, at every workplace, in every congregate setting, and every care facility.

So why on earth would you choose the Manhattan Project? The Manhattan Project was high science, and while its results were far-reaching, they were not adept at fighting a block-by-block war against an enemy. Nuclear weapons are a terrible weapon to use as a comparator when our moral task occurs on home soil. Likewise, the Apollo program may have spin-off technologies (famously, Velcro and Teflon) that are in every home, but none of those technologies got regular Americans closer to the stars.

At the risk of totally breaking the metaphor of health as security, there is one way to reconcile these visions. The weapon in mind is of a kind that *is*, statistically at least, in every American home: the gun. There are approximately 1.2 guns per American. They are easy to acquire, and easy to use for their intended purpose: taking lives.[45] More people know how to shoot, or could use a gun effectively in America, I suspect, than can don and doff a surgical mask appropriately.

In particular, I have in mind the Avtomat Kalashnikova, better known as the AK-47. As an innovation, the AK-47 is an ingenious but understated piece of hardware, and one of the most influential weapons in history. Its inventor, Mikhail Kalashnikov, described his inspiration in its design as arising during recovery from injuries in World War II. Asked by a fellow patient why the Nazis had automatic weapons, but the Red Army had only one rifle for two or three men, Kalashnikov was inspired to build his own: "I was a soldier, and I created a machine gun for a soldier."[46]

What made the AK-47 a machine gun "for a soldier" is what makes it a perfect analogical device for health security. It is designed, first and foremost, for easy mass production using the technology of the 1940s. Its pieces are machined or even stamped. Its reloading system uses a long-stroke piston which, while trading off against some accuracy, is incredibly reliable even under the worst conditions: sand, snow, mud, and water. Its parts can be riveted together, making them relatively easy to repair in a variety of low-resource conditions.

But its mastery is in its ease of use. The fire selector is located on the right of the rifle as a large lever. It doubles as a dust cover, and when in safe mode the charging handle (which pulls the bolt back into position to fire) cannot be retracted. The fire selector's modes, moreover, are arranged ingeniously: safe is all the way up, semiautomatic is all the way down, with full auto in the middle. This means that in a crisis a soldier is more likely to engage semiautomatic than full, which is safer for the soldier and their compatriots. And its trigger system is easy to use with gloves, or with small hands. It is an ideal exercise in human factors, if horrific in its impact.

The Kalashnikov reflects a design philosophy born of Soviet necessity. It does not necessarily reflect Soviet philosophical materialism; rather, it arrived in response to a war—the Eastern Front—that was catastrophically brutal for Russia. It reflects the insights of designers that fought in poor conditions, block by block, in inclement weather, with little training.

Let's consider some of the most critical needs for citizens, more or less everywhere, even if we assume that governments have the wherewithal and political will to institute justified public health emergency measures. They require respiratory protection of some kind and require it in sufficient quantity—either through replacement or sanitization—for the duration of any activities they do need to complete out of doors, or when dealing with sick family. They require a means to disinfect surfaces and potentially themselves. And they potentially require hand and eye protection. Everyone requires these, and they need to be able to be manufactured at scale, anywhere in the world.

Moreover, they need to be able to use these things easily, and without much training. N95 respirators are no good in a pandemic, it turns out, if they aren't able to be taken on and off by just anyone at any time and work no matter what. Hospital signs will notify patients that gloves may be more dangerous than bare hands because donning and doffing personal protective

equipment is not trivially easy. Personal protective equipment is, further, no good to most people if it is uncomfortable, because most people aren't medical professionals. Wearability and training are important. Human factors count, and it might be better to make small trade-offs in overall efficacy under proper use, for a much smaller chance of improper use. Or put another way, better they be pretty good and everyone can use them without thinking, than to be really good but only if you use them in a very particular way.

This technology, I suspect, does not exist yet—though after two years, I vouch for the KF94 mask design made and popularized in the Republic of Korea. Prototyping and testing it would not be easy. It would require a broad set of expertise to design, and a wide range of people to test in a broad range of conditions. But it would be a technology for the kind of war like COVID-19 is, and I suspect all infectious disease pandemics will be. It would be a technology anyone could use to defend themselves, and to support the war effort.

To my knowledge, the effort to make better PPE has largely stalled. And the effort to make *comfortable* PPE has never been high on people's list, at least relative to the priorities of major medical funders. This is fine when you are dealing with highly trained professionals who learn how to work with careful, technical equipment and to endure the distraction and discomfort as they work. It is not sufficient for individuals who, even if they train, will never train enough to use PPE appropriately, every time, at the standard of a healthcare worker.

This is the Kalashnikov approach in a nutshell. It does not apply merely to PPE; rather, it takes an approach where:

1. We ask who the technology needs to be for;
2. We determine under what circumstances it needs to be used;
3. We build the best thing we can that fits the broadest possible set of use cases.

Moreover, we build these technologies with a low manufacturing basis. It is not sufficient, for example, to expect individuals to all have 3D printers to make masks. Masks need to be built in places where there may not be 3D printers available. We may need a number of kinds of masks for different environments.

In war, this is a task for the state. The state may make use of private companies but ultimately, they are the arbiters of the kinds of technology

needed for the wars they intend, or foresee, fighting. A "lessons learned" plan for the next pandemic is incomplete if it ignores that high technology is, in virtue of its status, ill-suited for a prolonged siege.

Basic STEM for Complex Times

The need for novel therapies, interventions, materials, and strategies in the face of public health crises is not a new issue. And its connection to national security is also quite old. Writing in 1945, Vannevar Bush—himself part of the Manhattan Project—penned a letter to President Roosevelt called *Science the Endless Frontier*.[47] The letter sets forth a justification for basic science as an essential part of the US's postwar national security strategy. It is, Bush argues in *Endless Frontier*, instrumental to the nation's health, wealth, and security.

One of the lesser recognized problems that Bush foresees, however, is a dual public health crisis many of us are intimately familiar with: mental health and overdose. These are obviously not strictly connected but are related. Writing in the 1940s, Bush foresees a strategic problem if the nation becomes mired in mental health and drug overdose crisis. He articulates a vision of basic research into the causes of mental distress, and how to treat individuals suffering from substance abuse with compassion and care. Bush is writing a national security document, one of the foundational documents of the science-security complex. But within it, he treats a very real public health problem.

Bush's insight, however, brings out one lesson that the Manhattan Project can teach us. Bush articulated a program of basic science, conducted for its own sake, involving broad mandates for scientists to research problems deeply, not over years but decades. This is a broader vision born of the Manhattan Project, in which resources were leveraged to provide groups of scientists with the ability to pursue multiyear projects in a productive environment. The agency that would emerge from his vision is not the National Institutes of Health, but the National Science Foundation. While it would be a mistake to pretend that agency has lived up to Bush's dream, this is hardly its fault.

This science, moreover, should be broad spectrum. COVID has demonstrated that pandemics do not just require the life sciences. They challenge materials and chemical engineers, physicists, anthropologists, economists,

implementation scientists, psychologists, communication researchers, ecologists, and others. The flurry of biological and epidemiological research has not been as useful as it might have been in the context of the pandemic, not just because incentives within those disciplines are skewed, but because plenty of other knowledge is needed to handle pandemics. That knowledge, moreover, is probably best developed ahead of time, much as we develop operational and doctrinal knowledge ahead of war. We do not need to wait, in almost all cases, for the crisis to start to begin our research.

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