

Applied Science as a Political Construct: Scientific Legitimacy and Social Utility at the US National Science Foundation

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Abstract: *Applied science* is a ubiquitous term in fields ranging from history of science to innovation studies to science policy, yet its meaning remains elusive. While some historians suggest that its definition was stabilized in the early 20th century as part of the “linear model” of science, examples from the history of the US National Science Foundation show its meaning continued to be contested through the latter half of the 20th century. I argue that the term’s fluidity stems from its inherently political nature: the meaning of applied science changes to fit contemporary agendas. This essay identifies five criteria that have provided historical actors with a flexible set of discursive resources for constructing policy-relevant definitions of pure and applied science. This set of criteria provides historians with a way to systematically compare changing and competing definitions, and it exposes logical inconsistencies that point to *applied science* as a persuasive, rather than simply descriptive, term. I provide two case studies that illustrate how this works in practice: in the late 1960s NSF redefined applied science as “science that solves social problems,” while in the 1980s it promoted a meaning of “basic science that enhances economic competitiveness.” These redefinitions responded to contemporary political concerns, but far from being merely rhetorical, they shaped specific NSF programs and the types of science that were supported.

I. Introduction: The Many Meanings of Applied Science

Applied research can range from pure empiricism to abstract theory, from the highly particular to the very general, from a personal and individualistic effort to a highly scheduled and organized team effort. At one end of the spectrum, applied research is indistinguishable in its general approach and methodology from the purest type of basic research. At the other end it is best described as enlightened tinkering.

— Harvey Brooks, 1967¹

When Harvey Brooks, physicist and Dean of Engineering and Applied Science at Harvard University, was asked to prepare a 1967 National Academy of Science report on the state of “applied science” in America, he struggled to pin down a term whose meanings were multiple and in flux. Historians find themselves in a similar position. We use the term *applied science* as if its meaning were well understood, yet studies that focus on applied science have uncovered conflicting definitions. I argue that our collective difficulty stems from the fact that

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applied science is an essentially *political* construct, in two senses. First, within the scientific community, debates over the nature and place of applied science have reflected a jockeying for status among different fields. Second, government funding for research in applied science has been understood as a means to pursue economic or social policy aims. The politics of applied science have been reciprocally shaped by the practice of those fields deemed “applied”: as applied fields developed research infrastructure, theoretical depth, and technological achievements, they increased their political visibility and power; conversely, increased government funding has allowed those fields to further expand their size and intellectual scope.

Historians of science and technology have traced some of the changing meanings of applied science and the cultural implications of distinctions between applied and “pure” or “basic” science.² According to accounts by Graeme Gooday, Robert Bud, and Ron Kline that look at the US and Britain, in the 19th century the term *applied science* referred to craft or engineering knowledge that was developed independently of science.³ At century’s end, however, academic scientists began to advance a new view of applied science that gave it a subordinate status, using the term to denote the practical use of knowledge derived from “pure” science. This “linear model”—of pure science leading to useful applications by way of applied science—became dominant in the first half of the 20th century. While insightful, these historical analyses have been limited in both temporal scope and the actors and issues who take center stage. Few accounts go beyond the first World War, implying that by the early 20th century the term had reached closure and was no longer contested or reinterpreted.⁴ In addition, most of the historiographic debate has centered on questions about the sources of technological innovation and the status of engineers; in these accounts, “applied science” is often equated with technology—the practical *application* of science—rather than an area of scientific research in its own right. I will argue that far from being static, the term “applied science” was redefined more than once in the second half of the 20th century, and that it often referred not to technology or engineering but to an autonomous research activity comparable to “pure” science.

This article examines and problematizes the use of “applied science” in the US from the late 1960s through the early 1990s, using the National Science Foundation as a case study. Founded in 1950 to support “basic scientific research,” NSF provides an ideal site for investigating the politics of scientific taxonomies.⁵ The U.S. President (often with the input of a science advisor) appoints the NSF Director and the members of its oversight body, the National Science Board; he or she also proposes annual funding levels for NSF as part of the federal budget. Congress wields influence through annual budget hearings, and it periodically amends NSF’s authorizing legislation to reflect changing political priorities. Through this budget process, NSF’s research program is publicly debated and molded to reflect the President’s and Congress members’ political beliefs and priorities. Within NSF, scientific staffers craft funding programs that mediate between the agenda set by politicians and top NSF officials and the internally perceived needs, opportunities, and standards of their own scientific fields. These scientific fields are represented by the professional scientists who staff NSF’s program offices on a rotating basis, as well as the external review panels that approve grant proposals. As these various stakeholders debated NSF’s mission in the late 20th century, they offered multiple, sometimes conflicting definitions of applied science that reflected and advanced their own aspirations.

I collected public statements of these definitions by examining NSF publications, including its Annual Reports, organizational documents, websites, MOSAIC magazine, and National Science Board reports and strategic plans; Congressional hearings on the NSF budget;

recorded interviews with NSF leaders and oral histories of former NSF personnel conducted by the Charles Babbage Institute; and commentary in scientific magazines such as *Science*, *American Scientist*, and *Science News*. These documents capture a series of shifts and controversies regarding NSF's mission, from its commitment to "pure science" in 1950s and early 1960s through its embrace of engineering research in the 1980s and 1990s. From this dataset I identified five distinct criteria that were used at various times to differentiate "pure" and "applied" science:

- 1) *Object or domain of study*: Pure sciences study nature; applied sciences study the human-made world.
- 2) *Type of knowledge produced*: Pure research contributes general theoretical knowledge; applied research uses existing theory to create targeted practical knowledge.
- 3) *Motivation of researcher*: Pure researchers strive to create new knowledge regardless of its practical utility; applied researchers are motivated by practical goals.
- 4) *Autonomy of researcher*: Those doing pure science freely come up with their own research questions; those doing applied science are directed to study a particular problem related to the funder's mission.
- 5) *Target users of new knowledge*: Pure science creates knowledge that will be used mainly by other researchers; applied science creates knowledge that will be used mainly by people engaged in practical projects.

The heterogeneity of these criteria is striking: some refer to types of knowledge, others to qualities of the researcher, and still others to the actions of third parties (funders and users). They are also notably subjective, referring to individual researchers' motives and autonomy and to expectations about future users or theoretical breakthroughs. Individually problematic, when these criteria were combined they could become downright incoherent. For example, it was common to define basic science by the type of knowledge created (criterion #2) and applied science by its intended use (#3 and #5): but where did this leave the many researchers who were doing theoretical research with practical implications?

Yet the weaknesses and incompatibilities of these definitional schemes were largely overlooked in discussions about NSF. The fluidity of the term "applied science," as well as the actors' apparent disregard for coherent demarcation criteria, reinforce the term's status as a political category. As Thomas Gieryn has argued for the boundary between science and non-science, the boundary between applied and pure science was redefined opportunistically to suit the changing policy environment.⁶ An actor's use of the term "applied science"—or pointed refusal to use it—staked out a temporary position in the continually shifting debates over whose needs NSF should serve. Rather than imposing a stable meaning, such as might be implied by the linear model, the five criteria provide a flexible set of discursive resources for constructing *ad hoc* definitions.

While the terms "basic" and "applied" may not have corresponded to actual differences in research practices, these classifications were not merely academic; they had real-world consequences in terms of the funding, organization, and prestige of research areas.⁷ In the period I examine, there were two different political interpretations of applied science that had major implications for NSF. In the late 1960s-1970s, applied science was given a policy meaning of "science or engineering that addresses social issues," while in the 1980s-1990s the meaning

shifted to “basic science in areas that contribute to economic competitiveness.” In the following sections I describe how and why these two meanings were constructed and their consequences for NSF programs. We will see that the term was politically potent not just in spite of, but because of, its conceptual slipperiness.

II. Applied Research for Social Good, 1960s-1970s

In its first two decades, NSF largely dissociated itself from applied science. The 1950 Act authorizing the National Science Foundation never mentions the word “applied.”⁸ The creation of NSF had followed years of Congressional debate over the distinction between, and relative merits of, pure and applied science. While Senator Harley M. Kilgore’s original 1944 proposal for the NSF had prioritized applied research, it was Vannevar Bush’s vision of an agency to fund pure research, as articulated in his 1945 report *Science, The Endless Frontier*, that eventually won out.⁹ For Bush, the fact that applied science served practical public needs was, if anything, a reason for NSF *not* to fund it, for “Under the pressure for immediate results, ... *applied research invariably drives out pure*. The moral is clear: It is pure research which deserves and requires special protection and specially assured support.”¹⁰ Bush promoted the linear model of pure research leading to applied benefits, and he also reaffirmed a status hierarchy between pure and applied science, arguing that “students of the highest ability at the apex of the pyramid” should be encouraged to become basic science researchers, while lesser talents might find their proper place in industrial “applied science.”¹¹ In his introduction to the 1960 reprint of *Science, The Endless Frontier*, NSF director Alan Waterman lamented, “The general public is still far from a true understanding of the nature of basic research and of the fundamental difference between science and technology,” and he complained that too much federal funding was earmarked for “applied research and development.”¹² Before 1968, NSF’s Annual Reports rarely used the terms “applied science” or “applied research,” and most of these references were negative, denoting something that NSF did not or should not fund.¹³

By the mid-1960s, however, NSF was coming under pressure to make science more relevant to social needs. In his 1964 State of the Union speech, President Lyndon Johnson urged the creation of a “Great Society” that would eliminate poverty, racial injustice, and urban problems. Johnson associated these social goals with applied science, stating, “a great deal of basic research has been done.... But I think the time has now come to zero in on the targets by trying to get our knowledge fully applied.”¹⁴ In December 1964, retiring AAAS president Alan Waterman acknowledged “the changing environment of science” in his final presidential address. While noting that “to attempt to direct our efforts towards causes of national importance is ordinarily confusing and disturbing,” he described scientists as being pulled into social issues both by public demand and by scientists’ own “increased sense of responsibility for our future.”¹⁵ Americans in the 1960s began to critique the social costs of science and technology—from weapons of mass destruction, to environmental degradation, to computer threats to privacy—and to demand R&D that focused on solving issues such as pollution, urban blight, and energy needs. As Lucena describes, these concerns mobilized “a bandwagon of progressive groups that wanted to bring the NSF in touch with the nation’s social and environmental problems by supporting applied science.”¹⁶ Beginning in late 1964, Democratic Congressman Emilio Q. Daddario of Connecticut, who chaired the House committee that oversaw NSF’s budget, led a multi-year series of hearings about the future of the Foundation. Though known as an enthusiastic supporter of NSF, Daddario also wanted the agency to drop its opposition to

funding fields such as engineering, and he proposed an amendment to the NSF Act of 1950 that would expand NSF's funding mandate to include "applied research."¹⁷ In July 1968, through Daddario's efforts and those of his Senate counterpart, Edward M. Kennedy, that amendment was finally voted into law.¹⁸

Historians have recognized the significance of the "Daddario amendment" in broadening NSF funding to include both engineering and the social sciences.¹⁹ Before the Daddario amendment, the words "applied" and "application" had never been used in the names of any NSF directorates, divisions, or sections; afterwards, these newly respectable terms came into regular use.²⁰ But the law did more than elevate applied science at NSF; it also *redefined* applied science, in two ways. First, the Daddario amendment made clear that applied science could be considered a *research* activity—a practice of generating knowledge rather than merely utilizing it. The law explicitly categorized applied research as a form of science, rather than technology, stating that "the Foundation is authorized to initiate and support scientific research, including applied research."²¹ Another section spelled out that applied fields such as engineering and medicine were capable of "basic scientific research" at a level worthy of NSF funding.²² Second, the amendment enshrined the idea that applied science should be a lever for social policy. Reflecting contemporary popular and political efforts to make science serve social needs, under NSF's new charter the U.S. President could direct the Foundation to support "applied scientific research relevant to national problems involving the public interest."²³ These two ways of redefining applied science were mutually supportive. In order to justify NSF funding for socially-relevant projects, applied fields such as engineering and computer science had to be identified as research areas, rather than solely technology producers. Conversely, defining NSF's work as socially useful helped build public support for funding "basic" research in "applied" fields.

In addition to the wording of the amendment itself, scientists' testimony at the Congressional hearings and opinions expressed in scientific journals such as *Science*, *Science News*, *American Scientist*, and *Proceedings of the NAS* all demonstrate a shift in the meaning of "applied science" that elevated its intellectual status as a producer of original research while also equating it with service to humanity.²⁴ In a 1966 paper for *Science*, Don K. Price, Dean of the Harvard school of Public Administration, welcomed the new attitude spurred by Daddario as a revival of Senator Harley M. Kilgore's original populist vision for the NSF. "Senator Kilgore thought that the sciences could be advanced through subsidization as *applied* sciences.... assuming that the ultimate end of science was to solve social problems and advance the purposes of human welfare" (289). Price felt the proposed amendment would "let the nation devote a fair share of its science to applied programs affecting domestic prosperity and human welfare."²⁵ One of the most influential statements of the new definition of applied science as "socially relevant research" was a 1967 report by the National Academy of Science on funding needs in applied science, which Congress had requested to help inform debate over the Daddario amendment.²⁶ The panel that prepared the report was led by Harvard physicist Harvey Brooks, who chaired the NAS Committee on Science and Public Policy and was also a member of the National Science Board overseeing NSF. Brooks's introductory chapter (quoted earlier) wrestled with the definition of applied science, appealing to several of my five criteria.²⁷ In some cases he distinguished pure and applied science by their goals of conceptual understanding vs. practical application (#3, 24); other times he characterized the type of knowledge produced by basic science as general and abstract, while applied science knowledge was specific and concrete (#2, 22); elsewhere he invoked the actors' subjective views, so that the same research project could

be seen as “quite fundamental” by the investigator but “definitely applied” by the funder (#4, 22). But Brooks was consistent in describing applied science as a form of *research*, noting, “Work directed toward applied goals can be highly fundamental in character in that it has an important impact on the conceptual structure or outlook of a field” (24). He also emphasized that applied science was closely associated with public good: “important decisions in applied science depend not on technical feasibility ... but on social desirability” (41).

Responses to the 1967 NAS report and Daddario hearings showed prominent scientists divided over—but very aware of—the new valorization of applied science. Caltech President Lee A. DuBridge noted the pressure to make government-funded science “focus more precisely on the problems of war, of overpopulation, of urban living, of achieving a stable economy and a better way of life for all people” and grudgingly conceded that “applied science is important too.”²⁸ Frederick C. Lindvall, the newly elected President of the science honor society Sigma Xi, addressed its membership in early 1968 on the issue of “Science and the Social Imperatives.” Lindvall candidly admitted that the new emphasis on social relevance was unwelcome to many scientists, but noted that “lately the wind from Capitol Hill has turned a bit chill. Questions are being asked, objectives are being challenged, budgets are being cut, and demands are being made for research of immediate utility and application.” Lindvall recognized that applied science could be a policy tool—“Applied research, coming closer to social needs, merits support”—but he also emphasized the *research* side of applied science: “New basic information will result because frequently an effort to apply particular knowledge will disclose areas of ignorance in a well-established field or a weakness in the accepted theory.”²⁹

Other scientists were openly enthusiastic about the raised status of applied science. *Science* editor Philip H. Abelson, who had worked at the Naval Research Laboratory during WWII and spent the 1960s at the Carnegie Institution’s Geophysical Lab, praised the report for recognizing the scientific contributions of “mission-oriented laboratories” that “conduct excellent basic research while pursuing goals highly relevant to the needs of society.”³⁰ And at the November 1967 hearings on the Daddario amendment, several members of the National Science Board argued in favor of increased NSF funding for applied areas. In fact, the only expert at the hearings who spoke against the amendment was physicist and NAS President Frederick Seitz, who fretted that “it would be a great misfortune to the scientific community if the National Science Foundation, which has the obligation to support *science itself*, became involved in too much mission-oriented work of an applied nature.”³¹ Brooks responded, “I believe the National Science Foundation should support *scientific* research—that is, research that has scientific significance or practical significance (often both) extending well beyond immediate problems.”³² Brooks thereby reformulated the “type of knowledge” criterion (#2) to argue that applied science could produce knowledge of breadth and generality, rather than being narrowly practical. Seitz’s conservative view that “science itself” meant only pure science had been overtaken by a new orthodoxy that “scientific research” could also include applied science. Writing a few years later, Alvin M. Weinberg, Director of Oak Ridge National Laboratory, characterized applied science using the criterion of motive (#3), appealing to “founding fathers” of science such as Francis Bacon, “who observed that science was done because from science ‘we learn how to make two blades of grass grow where one grew before.’”³³ Weinberg predicted that the new association between applied science and social good “may change our relative valuation of the pure and the applied. Already we see a turning away, especially by younger scientists, from science that is remote and detached and a concern, even a yearning, for science that is relevant.”³⁴

Putting the new Definition of Applied Science into Practice: RANN

The changed meaning of applied science directly affected NSF's practices. For example, redefining applied science as "research for social good" provided the rationale for creating the first NSF funding office for computer science in 1967.³⁵ But the most visible consequence was a program called RANN. When William McElroy became NSF Director in July 1969, he looked for ways to expand the agency's funding of applied research in line with the Daddario amendment. His initial effort, in March 1970, was a modest program called Interdisciplinary Research Relating to the Problems of Society. The first IRRPOS grants included studies of genetic mutations from chemical pollution, fire protection, lead pollution, and "technical, economic, social, and political aspects of problems of environmental quality."³⁶ In December 1970 McElroy met with Office of Management and Budget chief George Shultz, who offered a deal: President Nixon would seek a multimillion-dollar increase in NSF's budget if the agency would use the money for science relevant to national needs. In response, McElroy hastily drew up plans for an expanded program called Research Applied to National Needs (RANN).³⁷ Nixon's new science advisor, Edward E. David, Jr., told *Science News* in January 1971, "The opportunity for both excellent research and new products and services in response to the needs of society ought to be the driving force in setting science policy."³⁸ Or as *Science* put it more cynically, "America might drown in sewage, choke on polluted air, run out of fuel, or fall into chaos from crime in the streets. But nobody will be able to say the National Science Foundation didn't try to help."³⁹

RANN reversed the linear model of research driving application. As NSF Deputy Director Raymond L. Bisplinghoff put it, NSF would ask, "What fundamental knowledge do we need in order to tackle some of these new national problems we are facing?" and then seek research proposals in those areas.⁴⁰ RANN was organized by problem areas rather than disciplines: initially Environmental Systems and Resources (weather modification, pollution); Social Systems and Human Resources (social science research, municipal operations research); and Advanced Technology Applications (a grab-bag including energy, earthquake, fire, urban engineering, enzyme technology, particle accelerator applications, and excavation technology).⁴¹ Energy became a major focus after OPEC imposed an oil embargo in October 1973, and it eventually absorbed half the RANN budget.⁴² When McElroy left NSF in February 1972, Nixon appointed as his successor Guy Stever—the first NSF director with an engineering rather than science background—who reiterated that "science has got to come to grips with the current problems of the Nation and society."⁴³

As it turned out, however, the triumph of socially-relevant applied science at NSF was short-lived. Despite Nixon's advocacy, RANN faced many obstacles. Many of the social problems RANN tried to tackle, such as poverty, racism, and global economic instability, could not be solved by a technological fix; as a result, RANN was tainted by the perception that it had promised more than it could achieve. Some of the programs were spread too thinly over a wide range of unrelated topics.⁴⁴ NSF did not have the management capabilities to oversee large applied projects (despite recruiting staff from NASA for this purpose), and scientists who were accustomed to working independently proved unwilling or unable to coordinate on large projects.⁴⁵ Many academics lacked experience in transferring the results of their research to users, and two reports by the federal General Accounting Office, in 1975 and 1976, found that RANN projects were not involving users closely enough in planning, conducting, or utilizing research.⁴⁶ GAO implicitly appealed to the criterion of "target user" (#5) to define applied

science as research shaped by the needs, preferences and knowledge of its intended users. RANN fared better at transferring knowledge to other federal agencies: its largest program, alternative energy, was transferred in 1975 to the new Energy Research and Development Administration (later part of the Department of Energy), while the Chesapeake Bay project was transferred to the Environmental Protection Agency and the fire research program to the National Bureau of Standards.⁴⁷

But RANN's biggest problem was the fervent opposition of many academic scientists and NSF staff, who feared "that RANN would drain funding from the traditional aspects of basic science."⁴⁸ McElroy ruefully observed on leaving the agency in 1972, "Perhaps we made a mistake in calling it applied research. Good science on major societal problems is not applied research."⁴⁹ Using my five criteria, we can see that RANN was "applied" in the senses of producing practical knowledge (#2) and targeting end-users (#5), but also—and most disturbingly to scientists—in the lack of autonomy for researchers (#4). As a *Science* reporter put it in 1971, "Much of the distinction between basic and applied research is in the eye of the beholder.... What makes RANN unique and controversial is not its support of applied work, but its orientation toward problems.... The objections raised against RANN challenge not so much the type of research that the program intends to support, as the notion of the NSF, the last bastion of basic research, funding goal-directed projects."⁵⁰ The NAS gave RANN's social science program a scathing review in 1976, claiming its research was "not impressive" and blaming this on RANN's "'top down character,' with problems being defined by the RANN staff and the 'user' community more than by investigators themselves."⁵¹

RANN was finally discontinued on the recommendation of the NSB in 1977.⁵² The remnants of its programs were merged into the Directorate of Engineering and Applied Science, which was itself replaced in March 1981 when NSF Director Slaughter, under pressure from engineers and their supporters in Congress, created a new Engineering Directorate.⁵³ NSF's own histories paint RANN as a mistake, calling it "one of the biggest controversies in the history of the agency," and a doomed endeavor: "Never warmly welcomed into the Foundation's scientist-dominated culture, RANN lurched forward until 1977."⁵⁴ But the perceived failure of RANN did not erase the lasting impacts from a decade in which NSF embraced applied science in the name of social utility. The Daddario amendment, which opened a place at NSF for applied research, remained law. "Applied" fields such as computer science and engineering had been recognized as areas in which basic research could be done, and their practitioners used this new scientific legitimacy to expand their presence at NSF, eventually getting their own directorates. More subtly, the arguments of prominent scientists that applied science included fundamental research, and not just technology or practical applications of research, had gained ground in policy circles and would be resurrected for new purposes in the 1980s.

III. Applied Research for Economic Strength, 1980s-1990s

When conservative Republican Ronald Reagan won the 1980 Presidential election, it became clear that NSF would no longer be viewed as a tool for social engineering. Some observers, however, expected Reagan to increase funding of applied science at NSF to support his economic agenda. A staffer for the House Science and Technology subcommittee predicted a shift from "Democratic science," in which the goal of basic research is to increase "the common welfare of the electorate," to "Republican science" that favors "research [with] obvious benefits, spinoffs and applications." *Science News* concluded that "applied science and engineering

represent the epitome of ‘Republican science.’”⁵⁵ *Science* reported in December 1980 that “The Reagan Administration is expected to be sympathetic to the new emphasis on applied science and engineering” represented by NSF’s recently-announced Engineering Directorate.⁵⁶ Engineers had even formed a political action group called Engineers for Reagan-Bush to show their support.⁵⁷

But Reagan and his advisors took a different tack: while they agreed that applied research was important, they wanted the private sector, rather than government, to take the lead.⁵⁸ During his campaign, Reagan had promised to cut government spending (except for a Cold War military buildup against the USSR) and to transfer many functions to the private sector. In 1984 Reagan appointed the first NSF Director to come from industry: Erich Bloch, a Republican who had been an engineer and executive at IBM. Bloch proclaimed that in his newly launched directorship, “the appropriate roles of government and industry have been better defined.”⁵⁹ He fell back on the old linear model to imply that funding pure research at NSF would lead to solutions to practical problems: “Today, we must be more vigilant than ever before about supporting the *basic* research required to keep our economy healthy and competitive—and our defense and social needs satisfied as well.”⁶⁰ In the Reagan administration’s view, it was neither appropriate nor necessary for NSF to fund applied science directly in order to meet social and economic needs. In addition to its small-government philosophy, Reagan’s approach reflected conservative Republicans’ reaction against some of NSF’s applied programs of the 1970s. Targeted programs included alternative energy research and a controversial social studies curriculum called “Man, a Course of Study” that critics accused of indoctrinating children with secular humanism and cultural relativism.⁶¹ Bloch described RANN as focusing on the wrong targets: “National attention shifted to social problems: housing, energy, crime. This was the heyday of ‘relevance,’ and research was directed toward these efforts, with little concern for economic competitiveness.”⁶² The scare quotes around “relevance” conveyed his disdain for the goal of addressing social problems with applied research.

Yet pressure was also building for federal funding of applied science in the name of a new policy goal: US economic competitiveness. Foreign competition, especially from Japan and Germany, was cast as an existential threat to the US, and commentators attributed the industrial success of these nations to their investment in applied research and development. Philip Abelson, editor of *Science*, voiced a popular view when he predicted in November 1980 that “future superiority will rest heavily on competence in applied science and engineering.”⁶³ Congress introduced over 200 bills to encourage “technological innovation” in 1983 alone.⁶⁴ Bloch got on board, warning in the National Science Board’s 1985 Annual Report that “Suddenly our industries must be concerned with global competitiveness if they want to survive.”⁶⁵

Political discussions of applied science infused it with a new meaning: science with the potential to improve national economic performance. This new meaning was reflected in the frequent use of terms like “capital” and “investment” as metaphors for applied research. In a June 1981 speech, Reagan science advisor George Keyworth told the AAAS, “New scientific knowledge and technological know-how represent our most productive capital today” and are “very much a part of the administration’s economic recovery plan.”⁶⁶ In an influential 1985 book called *Lost at the Frontier: US Science and Technology Policy Adrift*, science journalist Deborah Shapley and materials scientist Rustum Roy argued that NSF was failing to invest enough in applied science, a position they reiterated at a 1986 Congressional hearing on “Research Funding as an Investment.”⁶⁷ A 1989 NSF report argued, “Other nations tend to view their research efforts in conjunction with their economic competitiveness,” noting with concern that

“Europeans say that the Americans invest in Nobel prize science, and the Japanese invest in science that contributes to productivity and social welfare.”⁶⁸

How could NSF reconcile policymakers’ demands for research that could immediately benefit industry with its own traditional emphasis on basic science? The agency’s answer was to shift its characterization of engineering and other “applied science” fields, portraying them not as mere users of scientific knowledge but as participants in fundamental research. The rhetorical groundwork was laid in the National Science Board’s 1981 annual report, *Only One Science*, which was dedicated to rehabilitating applied science as a research activity. The title referenced Louis Pasteur’s maxim, “There are not two sciences. There is ONLY ONE SCIENCE and the application of science,” using the famous scientist’s authority to affirm that basic research could be done in any field.⁶⁹ In 1981 NSF also revised its peer review criteria to better serve applied research and engineering. In addition to scientific merit, reviewers would now consider “the utility or relevance of the research”: whether it provided “the basis for new or improved technology or assist[ed] in the solution of societal problems” and whether it helped build “the nation’s scientific and engineering research, education, and manpower base.”⁷⁰ The NSB’s 1988 report on “The Role of the National Science Foundation in Economic Competitiveness” argued that in the case of “engineering and in other technology-related fields... no dichotomy need be or should be drawn between ‘basic’ and ‘applied’ research.” The report referred to criteria of motivation (#3) and type of knowledge (#2) to characterize research in these technical fields as basic rather than applied: “Virtually all such research is ‘basic’ in that it is prompted by gaps in the store of scientific and technical knowledge... and strives to add to that store.”⁷¹ In 1989 Bloch lectured Congress, “Too many people think engineering has nothing to do with research. False. It has as much to do with research as science has to do with research. There is such a thing as a basic research effort in engineering.”⁷² Through NSF’s strategic blurring of categories, applied science could now be defined as “basic research that produces economic results.”

Putting the new Definition of Applied Science into Practice: NSF’s Centers

The imperative of economic competitiveness left NSF with a mandate to encourage the industrial application of scientific knowledge, yet both President Reagan and NSF officers were averse to funding applications directly. NSF could justify funding fields such as engineering and computer science by claiming that applied science was (or at least included) fundamental research, but this still left open the question of how that research would find its way into economically competitive products and services. The agency’s discouraging experience with RANN had shown that transfer of scientific knowledge to its target users could not be taken for granted. One important answer was a new institutional mechanism called NSF Research Centers. Bloch made NSF Centers his signature program for funding basic research that was uniquely positioned to be transferred to industrial application.

Bloch’s predecessor, NSF Director Edward Knapp, had set this in motion in December 1983 when he asked for the National Academy of Engineering’s advice on a proposal to create “engineering centers” on university campuses. A working paper from NSF’s Engineering Directorate explained that education had not kept pace with developments in industry; to address this, the proposed engineering centers would steer faculty and graduate students toward research in “the underlying engineering sciences in new fields (such as the use of computers in design and manufacturing)” while giving undergraduates “hands-on experience” in these areas. “Applications in industry [would] drive the research at universities” and industrial partners “would participate in the selection, review, and perhaps performance of the work.”⁷³ By

emphasizing “underlying sciences,” this proposal positioned applied scientists as basic researchers, while also heavily emphasizing the alignment of research with near-term industrial implementation. The research would be applied science by the criteria that practical goals would “drive the research” (#3), that researchers would have limited autonomy (#4), and that the target users would be industry (#5). NAE’s February 1984 report agreed that “the need for the engineering communities in both academia and industry to collaborate more closely is critical and overdue” and predicted that by encouraging such collaboration, “the Centers program will enhance significantly the future competitiveness of American industry.”⁷⁴ The Centers concept reflected the 1980s neoliberal doctrine of encouraging the private sector to commercialize government-funded research, but it also allowed NSF to promise an economic payoff from fundamental science.⁷⁵ The NAE report referred to the proposed facilities as “Engineering Research Centers” to emphasize that applied science was not merely the application of existing knowledge—a view that Bloch would go on to champion.

NSF announced the Engineering Research Centers in April 1984; in August Bloch was confirmed as Director. Bloch later recalled that in the aftermath of the “painful” controversy over the status of engineering at NSF, which had led to the creation of the Engineering Directorate in 1981, the ERCs helped reassure stakeholders that NSF was serious about supporting engineering research. During that controversy, “Some expressed the opinion that there was no such thing as research in engineering,” but “the establishment of Engineering Research Centers signaled to the community and the profession that there was such a thing as engineering research and that meaningful proposals would support that view.”⁷⁶ The centers were based at universities but included industry partners who contributed a share of the funding. Rather than its usual practice of funding academic science at arm’s length from industry, NSF had personnel from academia and industry work together at ERCs, in hopes of shortening the distance from theory to application. Each center pursued basic research on problems that industry had identified as important for future innovation in economically valuable areas, such as telecommunications, biotechnology, robotics, systems, and materials science. The first ERCs were funded in 1985, and by 1989 there were eighteen ERCs in areas ranging “from engineering design and intelligent manufacturing, to electronic materials processing and interfacial engineering, to telecommunications and optoelectronic computing systems, and to combustion engineering and hazardous substance control.”⁷⁷

Describing the new ERCs in *Science*, Bloch admonished its readers that “pure” scientists had paid too little attention to transferring their knowledge to users: “In recent decades we have moved away from the synthesis of theory and practice that the best scientists and engineers have always exemplified. We have let science become too much the property of those who define their subjects narrowly and who fail to seek connections ... between their ability to know and others’ ability to accomplish a practical end.”⁷⁸ Bloch sold the ERCs to Congress as a mechanism to ensure “knowledge transfer” to industry.⁷⁹ But a significant portion of this transfer would be indirect and gradual: a major goal of the Centers was to give undergraduate engineering majors realistic, hands-on experience so that they would be better prepared for future jobs in industry. A 1989 assessment by NAE downplayed immediate practical results, emphasizing the ERC program’s contribution to “the overall long-term technical strength of U.S. industry and universities” and referring to it as “a ‘seed corn’ program” that would grow “the fundamental knowledge and talent on which industry must draw as it struggles to compete in increasingly competitive and technologically driven markets.”⁸⁰ Applied science at the ERCs was strongly defined by the needs of their target users and the limited autonomy of their researchers to choose

problems, but its academic participants were also assumed to be motivated by a desire to create fundamental knowledge.

As soon as the ERCs had been launched, Bloch sought to expand the Centers idea to other areas of science. At a long-range planning meeting with the NSB in June 1985, he proposed doubling the Foundation's funding.⁸¹ As with the earlier RANN program, Bloch planned to court the White House by promising to devote the increased NSF funds to national needs—in this case, invigorating the US economy. Working with NSF's top-level scientific staff, he developed a proposal for Science and Technology Centers that would develop closer ties with industry and expand NSF to “become a central player in the Nation.”⁸² Industry leaders supported Bloch's ambitious plan, which helped win over President Reagan. As *Science* reported, the STC initiative “encouraged the Reagan Administration to embrace one of Bloch's central goals—a doubling of NSF's budget over 5 years,” adding that “any project aimed at restoring American competitiveness in high-technology industry was virtually guaranteed political support.”⁸³ Reagan announced the plan in his January 1987 State of the Union address, declaring, “It's widely said that America is losing her competitive edge. Well, that won't happen if we act now.... The Congress will soon receive my comprehensive proposals to enhance our competitiveness, including new science and technology centers and strong new funding for basic research.”⁸⁴

Bloch asked the National Academy of Science to study how best to set up the STCs, requesting them to identify “the most promising areas of science” related to “economic competitiveness” and stipulating that “industry and state participation is a prerequisite.”⁸⁵ Bloch's phrasing—and indeed the whole idea of Science and Technology Centers—alarmed some scientists. As reported by NAS panel chair Richard N. Zare, their concerns reflected meanings of applied science linked to researcher motivation (#3), autonomy (#4), and relation to users (#5). Zare warned of a possible loss of “individual initiative and scientific innovation” in “the center mode of research.”⁸⁶ The NAS report sought to define knowledge transfer in terms of education and intellectual exchange, not product development, and warned, “The objective of accelerating technology transfer could lead to a narrow focus on near-term commercial applications in center activities” at the expense of “scientific advances of greater long-term economic significance.”⁸⁷ The use of “technology” in the Centers' name seemed to prioritize practical utility over pure knowledge, and the requirement for state and industry involvement suggested that users would drive the research. The NAS panel sought to dodge these requirements by defining NSF's proposed centers as different from STCs that other agencies might establish in response to Reagan's directive: “Although the government-wide program for Science and Technology Centers should eventually embrace the entire spectrum from science to technology, the NSF portion of the program should focus primarily on basic science.”⁸⁸ Having stipulated that applied science at NSF should be seen as a basic research endeavor, the NAS agreed that “Centers can contribute to the nation's economic competitiveness by ... accelerating the application of new knowledge to the resolution of economically important problems.”⁸⁹

NSF selected the first eleven STCs in 1988 and they began operation in 1989; a second competition in 1991 resulted in 14 more STCs.⁹⁰ Research topics included storm prediction, cosmology, parallel computation, superconductivity, materials science, molecular biotechnology, and astrophysical research in Antarctica.⁹¹ The NSF's Centers have been judged largely successful by the agency and the scientific press. An official NSF history describes the ERCs in terms reminiscent of RANN's glory days, as “showcases of interdisciplinary research which is responsive to national needs.”⁹² Half of the funding for the ERCs came from outside NSF,

demonstrating buy-in from industry, universities, state governments and other federal agencies.⁹³ A 1989 assessment of the ERCs by the NAE declared, “If the federal government is to assist industry in its fight to remain competitive, this is precisely the kind of program that it should support.”⁹⁴ In a 1995 report, *Partnerships in Service to Society*, NSF Director Neal Lane praised the Centers for giving students “a perspective on industrial needs and a respect for careers in industry that in the past often were missing from the academic experience.”⁹⁵

Some of the fears attached to applied science Centers also came to pass. NAE reported that traditional single-investigator projects were getting less funding, leading to “tensions” between ERC and non-ERC faculty and “resistance” within NSF.⁹⁶ A 1991 *Science* article described the STC program as “a lightning rod for criticism ever since NSF first proposed it. Detractors call the centers a clumsy and expensive way of funding science” that “depriv[es] individual scientists of grants.”⁹⁷ Faced with tight budgets, NSF was accused of becoming “overzealous in pressuring ERCs to seek industry funding,” resulting in a research-for-hire mentality.⁹⁸

It also proved difficult to achieve “relevance” and “transfer” without sacrificing the autonomy associated with basic science. In the “Centers” model, the rapid commercialization of new knowledge would result not from limiting academic researchers to narrow practical problems—the old view of applied science—but from creating a space of physical proximity and personal interaction between academic and industry partners. NAE’s 1989 assessment emphasized that “The primary form of technology transfer at the ERCs is, and should be, through the research interactions with industrial scientists and engineers and the flow of students out of the ERCs into industry,” not “prototype development.”⁹⁹ But NSF’s deliberately vague model of knowledge transfer was hard to put in practice. A 1991 *Science* article on STCs commented, “Although they are philosophically committed to education and outreach, some of the centers seem to be groping their way in this area with no clear sense of direction.”¹⁰⁰ A 1998 study of federally-funded university-industry research collaborations found that “basic applied science” was not necessarily easy to exploit. To be successful, “Industrial participants in collaborative R&D projects with universities must invest in mechanisms to support the inward transfer and absorption of R&D results,” including “some level of in-house duplication of the R&D performed externally.”¹⁰¹ The hard work of bridging the gap between theory and practice did not generally take place at the Centers themselves; it was up to industrial members to make the results usable when they returned to their firms.

But a 1996 assessment by NAS declared the STCs a success, judging that “most STCs are producing high-quality world-class research that would not have been possible without a center structure and presence.”¹⁰² Resistance from other scientists may have dissipated in part because the program remained fairly modest, supporting 25 centers rather than the 100 that Bloch had originally envisioned.¹⁰³ In addition, the STCs had gravitated toward the traditional basic research paradigm, with their “paramount goals” understood to be “research and the undergraduate and graduate education linked to it.”¹⁰⁴ Bloch reflected in 2010 that the ERCs and STCs “were somewhat controversial at the time, but they have pervaded all research universities.”¹⁰⁵ Whatever their shortcomings, the Centers brilliantly solved NSF’s political problem of reconciling the imperatives to help the US economy through applied science while continuing to prioritize basic research. ERCs and STCs provided a mechanism to fund “basic applied science” and get credit for transferring that knowledge to industry, while avoiding becoming too involved in the final application of that knowledge.

IV. Unveiling the Politics: NSF's Taxonomy of science

A final example from the late 1980s reveals how NSF staff explicitly tied the tensions in federal civilian science policy to competing definitions of “applied research,” as they debated how the choice of terminology could affect which types of research would be funded and by whom. In August 1988, as the Centers were being established, NSF Director Bloch commissioned a task force to study the language used to describe pure and applied science. Referring to “the growing recognition of the importance of science and technology to national objectives,” Bloch charged the group to consider how categories could be made to fit and justify “NSF’s role in applied research, downstream technology research, and other activities that lie between applied research and proprietary activities.”¹⁰⁶ The resulting report on *Research and Development Taxonomy*, published in May 1989, was remarkably candid about the politics of R&D classifications. The task force made no pretense of creating an apolitical taxonomy, writing, “Three criteria that an R&D taxonomy should serve are: political sensitivity, policy usefulness, and statistical reliability.” “Political sensitivity” included “the ability to persuade research sponsors, budget-makers and decision-makers to meet requested budget levels and distributions.” For this reason, “The new definitions make the connection between the various roles of R&D funders and performers and economic competitiveness sharper.” The authors also noted that “the definitions are sufficiently broad so that they leave ample room for political maneuvering.”¹⁰⁷

The report proposed discarding the old dichotomy of basic and applied research and replacing it with three new categories. “Fundamental research” referred to “the part of ... basic research that is thought of as ‘pure’ research,” which is “designed to build the core of knowledge in a field.” At the other extreme, “Directed Research” supported “particular missions or products.” In the middle would be “Strategic Research,” which created knowledge “in an area of evident interest to a broad class of users external to the research community.”¹⁰⁸ This three-fold categorization followed a suggestion of Lewis Branscomb, then Chair of the National Science Board. Branscomb had proposed using the terms “fundamental research,” “problem-solving” research (done by and for a mission-oriented agency or business), and an intermediate category of “useful research,” which, unlike problem-solving research, would be “investigator-initiated” and “usually published in peer-reviewed literature.”¹⁰⁹ In both taxonomies, the middle category was meant to signal research that was economically relevant, but still basic, undirected science—the 1980s redefinition of applied science as I have described it.¹¹⁰

From a purely logical perspective, NSF’s proposed taxonomy was inconsistent, mixing incommensurable criteria. “Fundamental Research” was defined by the type of knowledge produced (#2), “Directed Research” in terms of goals and control by the sponsor (#3, #4), and “Strategic Research” in terms of its users (#5). Since these criteria are not mutually exclusive, the taxonomy did not provide a way to unambiguously assign research to a category. But from a political perspective, having an intermediate term between pure and applied science would allow NSF to claim credit for economic benefits without overly constraining researchers—and without overpromising immediate results, as RANN had done. Dian Belanger’s history of engineering at NSF describes how Branscomb was particularly anxious after the RANN debacle that “the phrase ‘applied science’ should be purged from NSF’s lexicon. It implied a commitment to solve a problem, and that, in turn, attracted ‘the political attention that does the mischief.’”¹¹¹ The category of “strategic research” was also meant to support NSF’s new Centers, which the report called “a clear example of research activity that has no place in the current taxonomy.”¹¹²

If defining research categories was a political exercise, assigning individual projects to the proposed categories would be fraught with uncertainty and gamesmanship. The sponsoring agency was supposed to assign categories based on who was expected to use the research (criterion #5).¹¹³ Branscomb defended this as being more objective than “the old definitions, which were based on the attitudes of the research performers” (#3).¹¹⁴ But the NSF authors admitted that researchers could game the system by claiming to have a target user for their research, shifting “fundamental” work to the potentially better-funded “strategic” category. Harking back to the RANN era, the authors cynically observed, “When NSF pursued research applied to national needs, any number of investigators could show how their work was germane.”¹¹⁵ The report also warned that funding for basic research could decline if strategic research became popular with “budget-maximizing bureaucrats,” concluding that their proposal was “a two edged taxonomy.”¹¹⁶ Perhaps for this reason, the new taxonomy was never adopted or widely publicized.

V. Conclusion

The second half of the 20th century saw substantial and self-conscious changes in how U.S. scientists and politicians defined the role of applied science. In the late 1960s and 1970s, applied science gained new respectability at NSF as a way to show scientists’ commitment to assist with national needs, especially social and environmental problems. A direct consequence of this view of applied science was the ill-fated RANN program, which sought to have NSF-funded scientists work directly with the intended beneficiaries of their work. The Reagan era brought changes in the policy objectives of applied science—primarily economic growth, with other social needs achieved only as a side-effect—as well as in how these objectives would be met: by private rather than public activity. NSF’s response was twofold: first, to emphasize that applied science was a form of fundamental research, and second, to create Centers as a new way of organizing NSF-funded applied science that put the responsibility for application in the hands of industry.

The competing and unstable meanings of applied science reflect an inherent tension between some actors’ desire to preserve freedom for researchers and others’ desire to steer NSF science toward socially relevant topics and to transfer results rapidly to industry. Using the deliberately ambiguous term “applied science” allowed NSF to paper over these differences in its pursuit of larger budgets. The lesson for historians is that “applied science” in post-WWII America—and perhaps elsewhere—should be treated as a political construct. Identifying the specific demarcation criteria that historical actors have used in different contexts can help to demystify the term and to reveal the hopes, fears, and policy positions that have attached to it.

Notes

1. Harvey Brooks, Introduction to *Applied Science and Technological Progress: A Report to the Committee on Science and Astronautics, US House of Representatives* (Washington, DC: National Academy of Sciences, 1967), pp. 1-2.

2. See especially the *Isis* Focus Section on applied science organized by Robert Bud (*Isis*, 2012, 103:3) and Paul Forman's extended essay in *History and Technology* and its responses (Paul Forman, "The Primacy of Science in Modernity, of Technology in Postmodernity, and of Ideology in the History of Technology," *History and Technology*, 2007, 23:1-152, <https://doi.org/10.1080/07341510601092191>).

3. Graeme Gooday, "'Vague and Artificial': The Historically Elusive Distinction between Pure and Applied Science," *Isis*, 2012, 103:546-554, <https://doi.org/10.1086/667978>; Robert Bud, 'Applied Science': A Phrase in Search of a Meaning," *Isis*, 2012, 103:537-545, <https://doi.org/10.1086/667977>; Ronald Kline, "Construing 'Technology' as 'Applied Science': Public Rhetoric of Scientists and Engineers in the United States, 1880-1945," *Isis*, 1995, 86:194-221, <https://doi.org/10.1086/357153>.

4. Narayanamurti, Odumosu and Vinsel do venture past WWII, discussing the use of "applied" in Donald Stokes's popular formulation (Venkatesh Narayanamurti, Tolu Odumosu, and Lee Vinsel, "RIP: The Basic/Applied Research Dichotomy," *Issues in Science and Technology*, 2013, 29(2): 31-36, citing Donald E. Stokes, *Pasteur's Quadrant: Basic Science and Technological Innovation*, Brookings Institution Press, 1997). But they still assume that use of the word "applied" implies the linear model of the early 20th century: "Stokes's framework preserves the language of the linear model in the continued use of the terms basic and applied" (p. 32).

5. National Science Foundation Act of 1950, PL-507, 81st Congress, 2nd Session.

6. Thomas F. Gieryn, "Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists," *American Sociological Review*, 1983, 48:781-795. Unlike Gieryn's case studies, where the object of boundary-work was to place the speaker on the "science" side of the boundary, in NSF's case the desirable side shifted between pure and applied science.

7. In focusing on the strategic ambiguity of applied science, I do not mean to imply that the definition of pure science was unambiguous or apolitical. But given NSF's mission, funding for pure research was relatively uncontroversial.

8. National Science Foundation Act of 1950.

9. Daniel J. Kevles, "The National Science Foundation and the Debate Over Postwar Research Policy, 1942-1945: A Political Interpretation of *Science—The Endless Frontier*," in Ronald L. Numbers and Charles E. Rosenberg, eds., *The scientific enterprise in America: Readings from Isis*, (Chicago: University of Chicago Press, 1996), 297-319, on pp. 308-309.

10. Vannevar Bush, *Science, The Endless Frontier* (Washington, DC: National Science Foundation, 2nd ed. 1960 [1945]), p. 83; emphasis in original.

11. Bush, *Science, The Endless Frontier*, p. 149.

12. Alan T. Waterman, Introduction to *Science, The Endless Frontier* (Washington, DC: National Science Foundation, 2nd ed. 1960 [1945]), vii-xvii, on p. ix.

13. National Science Foundation, *Annual Report*, (Washington, DC: NSF, 1959) repeats Bush's warning that "applied research drives out basic" (p. 11). The 1960 *Annual Report* argues

that “support should emphasize basic research” regardless of pressure to focus “upon any critical, practical problem, of either basic or applied science” (pp. 13, 15). The 1961 *Annual Report* raises the concern, “in what ways has ... the presence of large-scale applied research, altered the traditionally unfettered nature of university basic research?” (p. 153). In 1963 the *Annual Report* reassures readers that “The program activities of the Foundation’s Division of Social Sciences... have been concerned with basic research, not with studies of public policy, social issues, or other applied problems” (p. 28). The 1965 *Annual Report* states that science policy should determine how “support can best be provided for... basic science, as compared to applied science” (p. 157). The 1967 *Annual Report* repeats this conservative theme: “In May 1967, the National Science Board approved a policy statement on ‘Criteria for the Support of Research by the National Science Foundation’” that “restated the Foundation’s commitment to the promotion of basic research” (p. 7).

14. Lyndon Johnson, June 1966 White House statement, quoted in David Dickson, *The New Politics of Science* (New York: Pantheon, 1984), p. 29.

15. Alan T. Waterman, “The Changing Environment of Science,” *Science*, 1965, 147:13-18, DOI: 10.1126/science.147.3653.13, on p. 13.

16. Juan Lucena, *Defending the Nation: U.S. Policymaking to Create Scientists and Engineers from Sputnik to the ‘War against Terrorism’* (Lanham, MD: University Press of America, 2005), p. 56.

17. Science journalist Daniel S. Greenberg described Daddario as “almost embarrassingly friendly toward NSF” (Daniel S. Greenberg, “Basic Research: The Political Tides Are Shifting,” *Science*, 1966, 152:1724-1726, on p. 1725.

18. An Act to Amend the National Science Foundation Act of 1950. Pub. L. 90-407. 64 Stat. 149. 18 July 1968.

19. See Dian Olson Belanger, *Enabling American Innovation: Engineering and the National Science Foundation* (West Lafayette, IN: Purdue University Press, 1998), pp. 73-83, 95-96; William Aspray and Bernard O. Williams, “Arming American Scientists: NSF and the Provision of Scientific Computing Facilities for Universities, 1950-1973,” *IEEE Annals of the History of Computing*, 1994, 16(4): 60-74, on p. 67.

20. For titles of NSF units from 1950–1984, see National Science Foundation. *Organizational Development of the National Science Foundation, NSF Handbook Number 1* (Washington, DC: NSF, 1984).

21. Pub. L. 90-407, Section 3(c).

22. Pub. L. 90-407, Section 3(a)(1).

23. Pub. L. 90-407, Section 3(c).

24. It should be noted that discussions of applied science were still rare in these journals; most hits for the search term “applied science” merely list authors’ affiliations with schools of Engineering and Applied Science.

25. Don K. Price, “Federal Money and University Research,” *Science*, 1966, 151:285-290, 10.1126/science.151.3708.285, on p. 289, emphasis added. Vannevar Bush, on the other hand, continued to defend the NSF’s emphasis on pure science. When newly appointed NSF Director William D. McElroy asked Bush in 1970 about “the role and responsibility of the National Science Foundation in looking at some of the undesirable side effects on society of technological application,” Bush reiterated his warning that applied research would push out basic research and described contemporary problems such as pollution as “mostly a job for engineering, not science.” Of course, Bush was safely retired by then, while McElroy was in the

thick of the controversy. (William D. McElroy, "A Visit with Vannevar Bush," *Mosaic*, 1970, 1:8-13, on p. 10.)

26. National Academy of Sciences, *Applied Science and Technological Progress: A Report to the Committee on Science and Astronautics, US House of Representatives* (Washington DC: US GPO, 1967). This followed a parallel report on *Basic Research and National Goals: A Report to the Committee on Science and Astronautics, US House of Representatives* (Washington DC: US GPO, 1965).

27. Harvey Brooks, "Applied Research: Definitions, Concepts, Themes," in National Academy of Sciences, *Applied Science and Technological Progress*, pp. 21-56. An edited preprint of Brooks's chapter was published in *Science*, increasing the audience for his discussion about the meaning of applied science (Harvey Brooks, "Applied Science and Technological Progress," *Science*, 1967, 156:1706-1712).

28. Lee A. DuBridge, "University Basic Research," *Science*, 1967, 157:648-650, on pp. 648, 649.

29. Frederick C. Lindvall, "Science and the Social Imperatives," *American Scientist*, 1968, 56:303-311, on pp 309-310.

30. Philip H. Abelson, "Applied Science," *Science*, 1967, 156:1555.

31. *National Science Foundation Act Amendments of 1968, Hearings before the Special Subcommittee on Science of the Committee on Labor and Public Welfare*, United States Senate, on S. 2598 and H.R. 5404, Ninetieth Congress, First Session, November 15 and 16, 1967, p. tba, emphasis added.

32. *National Science Foundation Act Amendments of 1968*, p. tba; emphasis in original.

33. Alvin M. Weinberg, "The Axiology of Science: The Urgent Question of Scientific Priorities Has Helped to Promote a Growing Concern with Value in Science," *Amer. Scient.*, 1970, 58:612-617, on p. 613.

34. Weinberg, "The Axiology of Science," 614.

35. Janet Abbate, "From Handmaiden to 'Proper Intellectual Discipline': Creating a Scientific Identity for Computer Science in 1960s America," in Thomas J. Misa, ed., *Communities of Computing: Computer Science and Society in the ACM* (ACM Books / Morgan & Claypool Publishers, 2016), 26-46.

36. National Science Foundation, *Annual Report*, (Washington, DC: NSF, 1970), section 2, pp. 55-56.

37. Richard J. Green and Wil Lepkowski, "A Forgotten Model for Purposeful Science," *Issues Sci. Tech.*, 2006, 22(2):69-73 describe it as Shultz threatening to deny NSF any budget increase unless the National Science Board supported RANN (p 71). NSF's own account (George T. Mazuzan, "The National Science Foundation: A Brief History," <https://www.nsf.gov/about/history/nsf50/nsf8816.jsp>) is that Nixon was eager to have agencies spend more to stimulate the economy, and that the money would be split between RANN and programs pushed from DoD to NSF by the Mansfield Amendment.

38. "More Favor for Applied Science." *Science News*, 1971, 99(3): p. 44.

39. Robert J. Bazell, "NSF: Is Applied Research at the Take Off Point?," *Science*, 1971, 172:1315-1317, DOI: 10.1126/science.172.3990.1315, on p. 1315.

40. Bazell, "NSF," 1315.

41. Bazell, "NSF," 1316.; National Science Foundation, *Annual Report*, (Washington, DC: NSF, 1971), sections 2 and 5.

42. The National Science Board's 50th anniversary history states that the RANN energy projects "proved their worth" during the 1973 oil embargo (National Science Board, *The National Science Board: A History in Highlights, 1950–2000*, (https://www.nsf.gov/nsb/documents/2000/nsb00215/nsb50/1970/supp_dir.html, 2001), "Supporting the Director as Science Advisor."

43. Quoted in NSF biography of Stever, <https://www.nsf.gov/about/history/bios/hgstever.jsp>.

44. R. Jeffrey Smith, "More Fingers in the RANN Pie?," *Science*, 1977, 197:1347, DOI: 10.1126/science.197.4311.1347.

45. John Walsh, "National Science Foundation: Managing Applied Research," *Science*, 1972, 175:611-614, DOI: 10.1126/science.175.4022.611, on p. 612; Bazell, "NSF," 1316.

46. United States General Accounting Office, *Determination of the National Science Foundation's Progress in Implementing Recommendations Relating to the National Need (RANN) Program*, (Washington, DC: Comptroller General of the United States, 1977), 16.

47. Alfred J. Eggers, Jr., "Keynote Address: Making RANN Work," in *RANN 2: Realizing Knowledge as a Resource: Proceedings of the Second Symposium on Research Applied to National Needs* (Washington, DC: National Science Foundation, 1977), 25; Luther J. Carter, "More Stress on Applied Science at NSF," *Science*, 1979, 205:675-676, DOI: 10.1126/science.205.4407.675.

48. Mazuzan, "The National Science Foundation."

49. Walsh, "National Science Foundation," 611-612.

50. Robert J. Bazell, "NSF," 1315.

51. Constance Holden, "NAS Finds Flaws in RANN," *Science*, 1976, 191:1152, DOI: 10.1126/science.191.4232.1152.

52. Smith, "More Fingers in the RANN Pie?," 1347.

53. John Walsh, "NSF under Challenge from Congress, Engineers," *Science*, 1980, 209:1499, DOI: 10.1126/science.209.4464.1499; John Walsh, "NSF Boosts Engineering, Applied Research," *Science*, 1980, 210:1105-1106, DOI: 10.1126/science.7444437.

54. Mazuzan, "The National Science Foundation." The timeline on NSF's current website (<https://www.nsf.gov/about/history/timeline70s.jsp>, n.d., accessed 3/29/2019) also labels RANN "controversial."

55. Janet Raloff, "Science and Technology: The Next Administration," *Science News*, 1980, 118(20):314-315, on p. 314.

56. Walsh, "NSF Boosts Engineering, Applied Research," 1105.

57. Raloff, "Science and Technology," 314.

58. Mazuzan, "The National Science Foundation."

59. Erich Bloch, "Basic Research and Economic Health: The Coming Challenge," *Science*, 1986, 232:597-598, DOI: 10.1126/science.232.4750.595, on p.597, emphasis added.

60. National Science Board, *Annual Report* (Washington, DC: NSF, 1985), vi.

61. For cuts in energy research, see Deborah Shapley and Rustum Roy, *Lost at the Frontier: US Science and Technology Policy Adrift* (Philadelphia: ISI Press, 1985). For MACOS, see Mark Solovey, "The Impossible Dream: Scientism as Strategy against Distrust of Social Science at the U.S. National Science Foundation, 1945–1980," *International Journal for History, Culture and Modernity*, 2019, 7:209-238, DOI: <http://doi.org/10.18352/hcm.554>, on pp. 227-229.

62. Bloch, "Basic Research and Economic Health," p.597, emphasis added.

63. Philip H. Abelson, "Science and Engineering Education," *Science*, 1980, 210:965, DOI: 10.1126/science.210.4473.965.
64. Dickson, *The New Politics of Science*, p. 12.
65. National Science Board, *Annual Report* (Washington, DC: NSF, 1985), vi.
66. Keyworth quoted in Dickson, *The New Politics of Science*, p340 fn 54.
67. Shapley and Roy, *Lost at the Frontier*; Committee on Science and Technology, *Research Funding as an Investment: Hearings before the Task Force on Science Policy of the Committee on Science and Technology*, House of Representatives, Ninety-ninth Congress, second session, April 29, 30 and May 1, 1986, p. 324.
68. Task Force on Research and Development Taxonomy, National Science Foundation, *Report of the Task Force on Research and Development Taxonomy*, (Washington, DC: NSF, 1989), pp. 7, 29.
69. National Science Board, *Only One Science: Twelfth Annual Report of the National Science Board*, (Washington, DC: NSF, 1980), p. i., capitalized in original.
70. National Science Board and National Science Foundation Staff Task Force on Merit Review, *Discussion Report*, (Washington, DC: NSF, 1996), Appendix A; National Science Board, *A History in Highlights*, "Peer Review Broadened."
71. National Science Board, *The Role of the National Science Foundation in Economic Competitiveness*, (Washington, DC: NSF, 1988), pp. iii, 12.
72. Subcommittee on Science, Technology, and Space, *National science and technology policy: hearings before the Subcommittee on Science, Technology, and Space of the Committee on Commerce, Science, and Transportation*, United States Senate, One Hundred First Congress, first session, September 28 and 29, 1989, p. 195.
73. National Academy of Engineering Panel on Engineering Research Centers, *Guidelines for Engineering Research Centers* (Washington, DC: The National Academies Press, 1983), pp. 19-20.
74. National Academy of Engineering, *Guidelines for Engineering Research Centers*, pp. iii-iv.
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