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NSF and POSTWAR US SCIENCE

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In the early days of NSF, its leaders dreamed of large-scale federal investment in basic science but had to carve out a place for the new foundation in the complicated landscape of US science funding.

Editor's note: To mark the 75th anniversary of the creation of NSF, Physics Today *is reprinting this 2020 article about its early history.*

A crowd began to form at the train station in Pocatello, Idaho, around 5:15am on Wednesday, 10 May 1950. Some 700 bleary-eyed townspeople had come to see the president and neither the day's cold weather nor the hour would deter them. When the train chugged into town, President Harry Truman was standing on the rear platform, ready to greet the crowd. The trip to Pocatello was part of a whistle-stop tour of the northern US that took the president to numerous small towns dotting the railway.

Although Truman spent most of his time in Idaho addressing local agricultural and economic issues, in Pocatello, he talked to the crowd about science. Earlier that morning, as his train sped along the tracks, Truman had signed the National Science Foundation Act of 1950. It created the first federal agency devoted to supporting fundamental research and education across all scientific disciplines. Standing before a group of chilly Idahoans, Truman made a case for the importance of large-scale federal support for scientific research.

The story of NSF's creation and early years of operation serves as an important window into the growth of postwar federal science policy. Science's role in World War II had convinced many in the government that public support was needed for scientific research. Once open, NSF became an important site where debates over science policy, federal support for civilian research facilities, and federal support for education in STEM (science, technology, engineering, and mathematics) played out in postwar America.

NSF's World War II roots

In June 1940, anticipating that the US might decide to enter World War II, the US government created the National Defense Research Committee (NDRC). Its role was to supplement the military's ongoing R&D activities by enlisting civilian scientists and industrial research laboratories. Vannevar Bush (see figure 1), president of the Carnegie Institution of Washington and a member of the National Academy of Sciences, became the head of the NDRC and worked to bring US scientific research to bear on the war effort. By June 1941 the NDRC was expanded into the Office of Scientific Research and Development (OSRD). The NDRC had been created through an executive order and funded through the president's emergency funds; the OSRD, in contrast, was established under the Office of Emergency Management and had its own budget and a more secure organizational home in the White House. The OSRD also expanded the NDRC's work to include medical research and new capabilities for weapons development and testing.

Bush funneled unprecedented levels of funding through the OSRD into the hands of civilian scientists working in universities and industrial laboratories and helped expand and deepen federal connections to those institutions. Primarily through the mechanism of the research contract, Bush ensured that scientists played a greater role than they'd had during previous military engagements, when they served largely as consultants who directed federal dollars to scientific and technological projects they deemed most likely to yield strategic advantages.

By the end of the war, the OSRD had spent nearly half a billion dollars and made 2300 R&D contracts with 321 different industrial companies and 142 academic and nonprofit organizations. The contracts greatly favored the industrialized Northeast and well-established centers of academic excellence. The top four contractors by funding—MIT, Caltech, and Harvard and Columbia Universities—revealed the patterns of patronage the OSRD followed and helped entrench in the postwar period.[1]

The OSRD coordinated research that led to the tactical use of radar, the production of penicillin, and the development of the atomic bomb. In short, it revolutionized the relationship between US science and the state. By demonstrating the importance of federal support for scientific research, the OSRD cemented important financial relationships between academia, industry, and the government. Pleased with the OSRD's success, scientists and administrators began to advocate for continued federal support after the war.

Competing visions for postwar science policy

Bush and the other leading scientists at the OSRD were not the only ones with a vision for federally supported scientific research. In 1942 and 1943, Harley Kilgore, a Democratic senator from West Virginia who served on the Military Affairs Committee, introduced two bills calling for the creation of an office of science and technological mobilization. Although Kilgore himself was not a scientist, he had become persuaded that the nation should strengthen its scientific resources in the name of national defense. His bills outlined plans for a new federal office that would fund and conduct science and technological research, coordinate all federal and private scientific research, engage in international activities, and promote the training and education of future scientists.

Neither of Kilgore's initial bills made it out of committee, but his vision for postwar science policy was enough to arouse Bush's ire. In a 12-page letter to the senator, Bush outlined his objections to the 1943 bill. His chief criticism was that Kilgore's legislation conceived of science and technology's benefits to society too narrowly. He charged that Kilgore's bill advanced science in the name of military preparedness at the expense of science's primary aim of "increas[ing] the knowledge and the understanding of man … [and] extending his grasp of the environment in which he lives and his appreciation of the vast and intricate system of nature by which he is surrounded."[2]

His critique of Kilgore's proposal helped Bush frame his own vision for postwar science policy. He laid out his ideas in a July 1945 report titled *Science—The Endless Frontier*, which he prepared in response to President Franklin Roosevelt's request for a plan that would continue the successes of the OSRD into peacetime. His most crucial suggestion was for the creation of a national research foundation.

In the report, Bush made a strong case for why the federal government needed to support basic scientific research in the postwar period. The war had devastated the European centers of learning that had been crucial to the education of Bush's generation of scientists. "We can no longer count on ravaged Europe as a source of fundamental knowledge," he wrote. "In the past we have devoted much of our best efforts to the application of such knowledge which has been discovered abroad. In the future we must pay increased attention to discovering this knowledge for ourselves particularly since the scientific applications of the future will be more than ever dependent upon such basic knowledge."[3] To fulfill that goal, Bush argued that US universities and researchers would need more resources—and those resources could come only from the federal government. "New impetus must be given to research in our country. Such new impetus can come promptly only from the Government. Expenditures for research in the colleges, universities, and research institutes will otherwise not be able to meet the additional demands of increased public need for research."[4]

FIGURE 1. VANNEVAR BUSH, head of the Office of Scientific Research and Development during World War II and one of the architects of NSF. The photograph is inscribed to Hugh Dryden, director of the National Advisory Committee for Aeronautics. (Photograph from the National Archives and Records Administration, courtesy of the AIP Emilio Segrè Visual Archives.)

Without consulting Kilgore, Bush arranged for Democratic senator Warren Magnuson of Washington state to introduce a bill based on the ideas put forward in *Science—The Endless Frontier*. On Thursday, 19 July 1945, Magnuson introduced S. 1285, which had been drafted by OSRD staff with Bush's guidance. Kilgore reportedly considered himself "double-crossed" by Bush's move to undercut his efforts and decided to submit a new bill, S. 1297, the following Monday.[5] The stage was set for a protracted legislative debate that would last nearly five years. The main disagreements surrounded patent rights for government-funded research, support for the social sciences, geographic diversity of funding distribution, and political control of foundation operations.[6]

The NSF Act Truman signed into law in 1950 represented a compromise between the two camps. It called for the creation of a new organization that would develop a national policy for promoting basic research and education in the

natural sciences. The agency would have three main categories of functions: support for basic scientific research, support for science education, and the evaluation and exchange of scientific research and information. NSF would be led by a presidentially appointed director who would share planning and decision making with the National Science Board, a new advisory body comprising 24 representatives from the scientific community.

FIGURE 2. THE US CAPITOL BUILDING in Washington, DC, where Congress votes on legislation and budgets. (Photo by Martin Falbisoner, CC BY-SA 3.0.)

Should there be a national policy for science?

NSF was born into a complex federal R&D landscape that skewed heavily toward research focused on national security. At the time of NSF's creation, the newly organized Department of Defense and the Atomic Energy Commission accounted for 90% of the $1 billion federal R&D budget[7] in 1949–50. Although Bush had hoped NSF would become the centralized place in the federal government for medical and military research, other agencies remained involved. The military services continued their individual basic research programs; the AEC and the Office of Naval Research maintained their support of fundamental science related to nuclear research and the operational needs of the US Navy; the National Institutes of Health became the primary patron of medical research. Such competition, along with the outbreak of the Korean War, led to meager initial budgets for the fledgling NSF. Congress voted to appropriate just $225 000 (around $2.4 million in current dollars) for NSF[8] in fiscal year 1951 (see figure 2).

The man charged with staffing NSF and building operational capacity with that shoestring budget was Alan Waterman (see figure 3), a seasoned science administrator who had worked for Bush's NDRC and served as the Office of Naval Research's first chief scientist after the end of World War II. A short, silver-haired man with square features and a stocky, athletic build, Waterman was 58 years old when Truman appointed him as NSF's first director. During his 12-year term—the longest tenure of any NSF director to date—Waterman carefully paced the agency's growth, making decisions that would shape both its development and the landscape of federal civilian research funding.

The NSF Act laid out science policy and evaluation duties for the new foundation. Waterman was careful not to take on too much, too quickly. In the first few years of NSF's existence, Waterman worked closely with the Bureau of the Budget to work out the agency's scope and organization. The bureau, a predecessor to the Office of Management and Budget, had been tasked with implementing the president's strategies by issuing organizational directives to government agencies and setting budget priorities. Influential members of the bureau had become concerned about the proliferation of basic research programs across various agencies and in the DOD. They viewed NSF as an opportunity to rein in federal R&D programs and eliminate any potential duplication of efforts by centralizing control and evaluation in one agency.

Waterman and the National Science Board, however, recognized that the fledgling agency would face great operational difficulty if the bureau successfully saddled it with the herculean task of coordinating and evaluating all federal R&D programs. That would have required NSF to request detailed information about funding priorities and research performance from all existing federal science programs. They argued that the agency didn't have the necessary legal authority to evaluate and give direction to sister agencies and that such duties fell under the direct purview of the bureau. Waterman also disagreed with the bureau about how much control NSF should attempt to exercise over the direction of US science policy. "Those who insist that policy must be handed down 'ready-made' in the form of a proclamation or edict do not understand the nature of policy in the realm of science," he later wrote in a retrospective for *Science*. "To be workable, policy must evolve on the basis of experience; further, it must take fully into account the fundamental principles essential to the effective performance of research in science."[9]

Under Waterman's leadership, the foundation organized its operational activities and policymaking around the central belief that scientists, not government agencies or administrators, knew best how to organize and conduct scientific research. Therefore, the agency's process of evaluating proposals and awarding grants relied on the expertise and advice of scientists, which they solicited through in-person panels and mail-in proposal reviews. NSF's approach to policymaking also relied on information from the scientific community and careful policy studies and statistical surveys to produce general recommendations. A significant early example of that approach was the foundation's decision to support the development and operation of national research facilities.

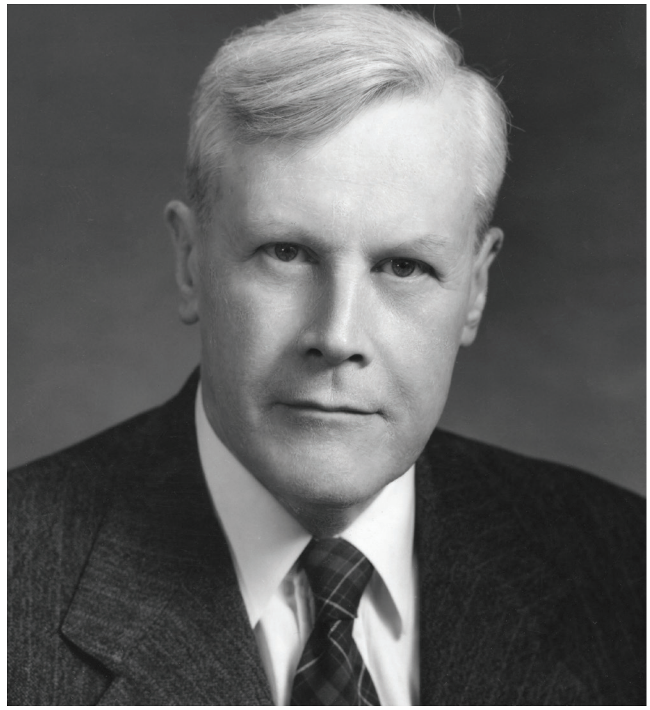

FIGURE 3. ALAN WATERMAN, first director of NSF. (Photograph by Harris and Ewing, courtesy of the AIP Emilio Segrè Visual Archives, PHYSICS TODAY Collection.)

New centers for research

Although NSF's budgets remained modest during its early years, the agency's policy decisions played a crucial role in establishing civilian-led, basic research in the military-dominated federal R&D landscape. The rising cost of conducting cutting-edge scientific research limited many researchers' access to essential equipment. After World War II, defense agencies and industry made large capital investments in research facilities, but those laboratories were largely occupied by military and industry-sponsored researchers working toward mission-oriented goals. When proposals requesting funds for research facilities in nuclear physics, astronomy, and computing began arriving at NSF offices, the leadership saw an opportunity not only to support individual research projects but also to encourage the construction and operation of entire facilities for civilian-led, basic scientific research.

Although the agency's original mandate did not mention research facilities specifically, the National Science Board at its May 1955 meeting adopted an official policy regarding facilities investment. It directed NSF to support large, basic scientific facilities "when the need is clear and it is in the national interest, when the merit is endorsed by panels of experts, and when funds are not readily available from other sources."[10] The facilities policy created a new budget category, "special budgets," to ensure that the funds for large projects were kept separate from research funds for individual investigators and small-scale projects. In presenting the new policy to the White House, Waterman justified the expansion of NSF support for civilian-led basic research facilities by pointing out that various defense agencies had also funded facility construction to support mission-related research.

NSF hoped that the facilities it funded would both improve the quality of basic research in fields that depended on specialized and costly equipment and redress geographical imbalances in equipment location. The US's leading research facilities and best equipment tended to cluster around elite universities on the East and West Coasts, and NSF recognized that researchers in other areas of the country encountered more difficulty gaining access to equipment such as large telescopes and particle accelerators.

NSF submitted its first request for construction funds to Congress for FY 1956. During that year the agency awarded \$125 000 for grants to support research facilities in biological and medical sciences and \$397 500 for facilities to support mathematical, physical, and engineering sciences.[11] The facilities grants represented only 3% of the agency's total financial obligations for FY 1956, but they supported a wide range of projects: the beginning phases of construction of a national optical observatory on Kitt Peak in Arizona and the National Radio Astronomy Observatory in Greenbank, West Virginia; a nuclear reactor at MIT; several biological research field stations; and computing centers at Caltech, MIT, Oregon State College, the University of Washington, and the University of Wisconsin.[12]

NSF's early investment in astronomy, in particular, demonstrated the importance of the agency's support for fundamental, scientific research as a balance to military and private funding sources. In contrast to mission-related research, which guided the direction of scientific inquiry toward specific aims, NSF support offered astronomers access to observatories regardless of institutional affiliation and the chance to pursue curiosity-driven research. (See Patrick McCray, "The contentious role of a national observatory," Physics Today, October 2003, page 55.) NSF's early support of astronomy facilities also illustrates how the needs of the scientific community shaped agency priorities, and it served as an early example of the type of "bottom-up" science policy formation that Waterman championed.

Influencing federal STEM education policy

Support for US STEM education also became a fast-growing area of investment for NSF during its first decade. Before 1958 the federal government primarily left education funding and support to individual states. Wide variation in public schools' funding led to large discrepancies in education quality and access between towns, cities, and states.

Although the US government had passed various measures to provide funding for agricultural and vocational schools during the early 19th and 20th centuries, federal investment in education remained a politically contentious issue. The political landscape began to change, however, when concerns about scientific manpower started to chip away at long-held resistance to the idea of federal education funding. After World War II, scientists began to directly connect the state of US education with national security concerns. In *Science—The Endless Frontier*, Bush had warned that the US would emerge from the war with a grave shortage of scientists. He had also expressed great concern over the state of US math and science education, saying that schools were failing to produce enough high-quality scientists and that the US needed them to secure the national defense. The growing specter of Soviet competition during the 1950s added increasing urgency to his warnings.

The NSF Act gave the foundation a broad mandate to support science education. Immediately after its creation, the agency initiated a program of support for a range of science education activities, beginning with the Graduate Research Fellowship Program in 1952. Although the majority of NSF's initial education programs focused on the university level, it became increasingly clear that major improvements needed to be made at the secondary level. NSF officials were initially hesitant to venture into the comparatively more politically contentious realm of precollege education, but they recognized the need to assist science, math, and engineering teachers whose training had become outdated after the rapid scientific developments during World War II. One NSF-supported study from the period found that the average public high school math teacher had some college coursework in math but had not majored in the subject.[13]

Strengthening high school STEM courses through improved teacher training became a focus for the agency. In 1954, scientists, mathematicians, and NSF staff members began organizing training programs for high school and college teachers at university campuses across the country. The Institutes Programs sought to update teachers' subject knowledge to include the latest scientific advancements, upgrade teachers' basic training in their subject areas, and increase teacher familiarity with the latest STEM curricula—some of which had been developed with NSF support.[14]

FIGURE 4. A REPLICA OF *SPUTNIK 1* (right) and a 1957 Soviet stamp **(left)** commemorating the successful launch of the satellite. (*Sputnik 1* image courtesy of the Smithsonian National Air and Space Museum; stamp is PD-RU-exempt, via Wikimedia Commons.)

The postwar fears about Soviet competition that had largely fueled congressional support for NSF's secondary education programs reached a fever pitch on 4 October 1957. The Soviet launch of *Sputnik 1*, the first artificial, Earth-orbiting satellite, sent shock waves throughout the US (see figure 4). The subsequent launch on 3 November of *Sputnik 2*, which carried a dog named Laika, prompted an alarmed Congress to summon scientists, including Bush, to testify in public hearings later that month. Legislators wanted to know why Soviet developments had seemingly eclipsed US capabilities and what could be done to regain the US's position as the global leader. In response to those questions, Bush reiterated one of his key points from *Science—The Endless Frontier*: that US scientific and technological competitiveness depended on a strong system of scientific education and training.

The Sputnik program became a potent symbol of the damage that US underinvestment in science education and research might cause to national security and prestige. Congress responded with across-the-board increases for federal science support. For FY 1959, NSF received a total budget of $132 940 000, nearly triple the FY 1958 budget. NSF's education programming received the largest boost from the post-Sputnik influx of funds, taking in a total of $62 070 000 for FY 1959—over $12 million more than NSF's entire budget from the previous year.[15]

Although the Sputnik program spurred Congress to provide much-needed financial support for the agency's ongoing education programs, it also increased political pressure on President Dwight Eisenhower's administration to formulate a strong, far-reaching education policy. To help craft it, the White House turned to NSF, which, as a federal innovator in the field, could boast a well-established record in science education programming. On 27 January 1958, the White House released its plan for strengthening US education. Eisenhower's accompanying statement explained that his administration had developed the proposed program in consultation with the directors of NSF and the Office of Education. He included high praise for NSF's science education improvement efforts, calling them "among the most significant contributions currently being made to the improvement of science education in the United States."[16]

NSF STEM education activities served as a model for the STEM-focused parts of the 1958 National Defense Education Act (NDEA), which Eisenhower signed into law on 2 September 1958. It transferred $1 billion to the Department of Health, Education, and Welfare for the administration of a need-based loan and college fellowship program, the expansion of school science labs and foreign language instruction, and the creation of state programs to improve science and mathematics education. The first example of comprehensive federal education legislation, the NDEA formed a cornerstone of a postwar federal strategy focused on strengthening the US scientific and technological workforce that continues today.

Foundations for future science and education policy

Even though the agency did not immediately become the counterbalance to military and applied research that many had hoped it would be, the strategic investments made during NSF's early years in fields such as science education and research infrastructure support made it possible for the foundation's limited budget to have an outsized impact. The early budget restrictions also revealed to agency leadership that the link between basic research and national security was not a firm one. NSF's place in the federal funding landscape would need to be perennially justified and reasserted through the lens of an ever-changing geopolitical and fiscal landscape.

During the first 12 years of the agency's existence, Waterman charted a course of steady, considered growth. In the face of attempts to saddle NSF with burdensome duties, Waterman kept the foundation true to its core mission: the support of fundamental science research and education. Although he often drew criticism from government officials and fellow scientists for his cautious approach, many observers attributed NSF's survival during lean budgetary years to his prudence and planning. His work positioned NSF for the rapid expansion it experienced at the end of the decade.

Waterman's guidance of the agency won the respect of Eisenhower as well. In a letter dated 6 January 1961, just two weeks before his departure from the Oval Office, Eisenhower wrote to Waterman to praise the foundation's work during his administration. Professing his wish to "pay tribute" to Waterman and NSF's staff for their work promoting the progress of science, Eisenhower reflected with pride on the fact that NSF appropriations had risen drastically during his administration, from $4.7 million in 1953 to $154.7 million in 1960. He noted that NSF served as an "excellent barometer" of the nation's response to the urgent need for "increasing the scientific effort."[17]

In the 60 years since Eisenhower stepped down, NSF has also served as a barometer of the nation's attitudes toward and concerns about government support of basic science. Many of the debates that existed at the time of NSF's creation—the extent to which the agency should fund applied research, the appropriate level of support for social-science research, the geographic distribution of research funding, and more—have continued to shape agency policy throughout its 70 years. Changing political, economic, and social forces, however, have given rise to new concerns. In recent years, attention to access and equity has driven a range of different agency initiatives focused on increasing the participation of women and minorities in STEM research and careers. New geopolitical tensions have given renewed urgency to the challenges of balancing national security with scientific openness and collaboration. Like science itself, NSF's programs and ambitions have never been static; they have evolved and changed in response to policy debates, public opinion, and the needs of civilian researchers in the US.

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