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US science and technology: An uncoordinated system that seems to work

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ABSTRACT

The US has emerged as the world leader in science and technology research and development in the 60 years following World War II. This status is due, in part, to a successful public–private partnership in research and higher education fostered after the war, and to the fiercely competitive and innovative nature of US industry. This paper provides some background to the complexities of US federal funding of research and development, as well as a brief history of US science and technology policy following World War II. The paper describes how research is managed and funded in the US; outlines how the US federal government interacts with universities and private industry; remarks on the nature of international cooperation; and comments on the future direction of US science and technology policy, including growing challenges to its position of leadership.

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1. A brief history of modern US science and technology policy

1.1. A new role for government following World War II

Prior to World War II (WWII), American scientists had already begun to form alliances with businesses and the federal government in both the civilian and military sectors by persuasively advocating the value of science as a basis for innovation [1]. But it was in WWII that the US and its allies saw in stark terms the power of science and engineering research and development (R&D), given the strong impacts of radar, sonar, the proximity fuse, early computers, synthetic rubber, penicillin, sulfa drugs and other important innovations that contributed to the nation's successful wartime effort [2–12]. However, the icon—and shadow of things to come—for science, physics in particular, was the Manhattan Project and the atomic bomb [13,14].

As the war drew to a close, Vannevar Bush, director of the Office of Scientific Research and Development (OSRD) and wartime advisor to Presidents Roosevelt and Truman, wrote the legendary report *Science*: *the Endless Frontier*, in which he argued that science and engineering R&D, which proved essential to a successful wartime effort, would be vital to the nation's future peace and prosperity [5,15,16]. With the encouragement of his academic colleagues, Bush argued forcefully

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that most of the nation's federally funded research should be carried out in universities, where many of the best scientists[1] were located and where future generations of scientists and engineers would be educated.[2] Bush's report and subsequent government actions established, at least in the minds of academic researchers, an unwritten compact between US science and the American public, whereby the federal government would use tax dollars to fund academic research. In turn, university researchers would carry out the research with their students, publish the results in the open literature, and produce the next generation of scientists and engineers. This notion set the tone for the next half century of US federal support for research and higher education. Moreover, with passage of the GI Bill (Servicemen's Readjustment Act of 1944), a large number of returning WWII veterans entered universities across the country, and many of them had received technical training during the war [9]. The Bush report also underscored the value of integrating research and formal education and led to the flowering of the American research universities[3] and to the establishment in 1950 of the National Science Foundation (NSF), a new agency focused on academic research and education [4,5,10,16–22].[4]

In the 5 years following WWII, Congress established, in addition to the NSF, the Office of Naval Research (ONR), and the Atomic Energy Commission (AEC), which evolved into the Energy Research and Development Administration (ERDA) in 1975 and the Department of Energy (DOE) in 1977. These agencies, along with the National Institutes of Health (NIH), parts of which date from the 19th century, and the National Aeronautics and Space Administration (NASA), and several defense agencies—including the Air Force Office of Scientific Research, the Army Research Office, and the Defense Advanced Research Projects Agency (DARPA or, in some years, ARPA)—are the main players in US federal science and engineering R&D today [23].

Universities were not the only federally supported research institutions. Government-operated (intramural) laboratories like those of NIH and most NASA centers, as well as federally funded R&D centers (FFRDC), such as Fermi National Laboratory, Jet Propulsion Laboratory, National Center for Atmospheric Research, the MIT Lincoln Laboratory, and a number of DOE general-purpose and weapons laboratories, would also pursue a large portion of US R&D.[5] These national laboratories were expected to provide a service that was complementary to that of the universities, for example, by constructing and operating large research facilities.[6] It was also anticipated that national laboratories would maintain a cadre of excellent scientists and engineers who could focus their minds and energies on national needs in addition to generating new fundamental knowledge and technologies through basic and applied research. Private industry also made substantial investments in R&D; early examples were the laboratories operated by Bell Telephone (Bell Labs) [24], Hewlett-Packard, General Electric, Westinghouse, IBM, Texas Instruments, and Xerox.

1.2. Science and the Cold War

The end of a horrible world war and the ensuing reconstruction under President Truman's Marshall Plan soon gave way to the Korean and Vietnam conflicts and a lengthy nuclear arms-race standoff with the Soviet Union. As the Cold War continued for nearly a half century, the framework and goals of US foreign policy and science policy were affected. Federal funding of R&D, which grew steadily after WWII, jumped abruptly during the Eisenhower administration as the direct result of the Soviets' surprise launch of *Sputnik I* in 1957 (see Fig. 1). Concerned that the US would not have the scientists and engineers needed to win the space race with the Soviet Union, Congress passed the 1958 National Defense and Education Act (NDEA), which provided fellowships and low-interest loans to college and university students [4].

On September 12, 1962, President Kennedy gave his famous "Americans go to the moon" speech in the Rice University football stadium, saying "We choose to go to the Moon in this decade and do other things, not because they are easy but because they are hard!"[26]. The year before, Kennedy had decided that the US would leapfrog the Soviets' space efforts by

[1] In this paper, depending on the context, the term "scientists" will include researchers and technical experts not only in the physical, biological, computer, mathematical and social sciences, but also in engineering and medicine.

[2] Bush also maintained, with great zeal, that research in all fields (including biomedical research) should be supported by a new non-defense federal agency, which he called The National Research Foundation. He believed that even military research should be in civilian hands. One of Vannevar Bush's original objectives—to consolidate research funding under one federal roof—was not realized, and that topic has been revisited, off and on, for decades [5,15–16].

[3] US universities spend about $40 billion per year on R&D ($25 billion from federal agencies and $15 billion from non-federal sources) and carry out 14% of all US R&D activity; 33% of the nation's research (basic and applied); and 54% of the nation's basic research [50].

[4] The NSF is a unique federal agency in many ways. It is the only agency with the broad mission to "promote the progress of science; to advance the national health, prosperity, and welfare; and to secure the national defense." Over the years, its mission was expanded to include engineering; science, mathematics, and engineering education; and the social sciences. It was never focused on "national defense" *per se*, unless one includes its contribution to America's scientific and technical capability. The NSF is also unusual in having a National Science Board, made up of 24 members, appointed by the president and confirmed by the Senate, which shares policymaking authority with the director, who also serves ex officio on the Board.

[5] The FFRDC's are R&D laboratories that receive most of their funding from the federal government but are operated by a non-government entity; collectively, the FFRDCs perform about 8% of all US federal R&D. For example, the US high-energy physics laboratory, Fermi National Accelerator Laboratory (FNAL), or FermiLab, is operated by Universities Research Association, Inc. (URA), a non-profit corporation, which was created to compete for a Department of Energy contract to operate FermiLab. URA also won the contract to manage and operate the cosmic ray facility, Pierre Auger Observatory. At the present time, FermiLab is managed and operated by a partnership (the Fermi Research Alliance LLC) between URA and the University of Chicago.

[6] In FY2006, federal funding (obligations) for the federal intramural R&D laboratories amounted to about 25% of total federal R&D spending, thus exceeding federal funding to universities and colleges, which is about 21% of the total. Industry receives the bulk of federal R&D dollars, about 40% in 2006, most of which comes from defense contracts [54].

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