Science, Universities, and National Defense, 1945–1970

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I. THE DEFENSE ESTABLISHMENT AND ACADEMIC SCIENCE

THE HISTORY OF UNIVERSITIES AND THE HISTORY OF SCIENCE have been closely intertwined throughout the twentieth century. Their common strands became all the more tangled after World War II, when the federal government began sponsoring the preponderant share of academic research.[1] Federal support of academic science in fact represents a multitude of relationships. The funding of agricultural research in universities has a history extending back to the Hatch Act of 1887. Patronage of biomedical research began in earnest when the Public Health Service assumed wartime contracts. It expanded greatly during the years that James Shannon directed the National Institutes of Health (NIH; 1956–1968) so that approximately half of federally supported academic research is in this area.[2] The National Science Foundation (NSF), which Vannevar Bush had proposed as *the* conduit for federal support for science, was not enacted into law until 1950, and only became the pillar of support for basic academic research outside of biomedical fields in the early 1960s. Yet another source of funds for university scientists was the defense establishment—the armed services, the Atomic Energy Commission (AEC) and its successors, and later the National Aeronautic and Space Administration (NASA).[3] The link between defense and the university has been most problematic for both contemporaries and historians.

Immediately after the war, aside from the Department of Agriculture, virtually all federal support for university research was supplied by the armed services. Most of this support consisted of funds and projects that were "in the pipeline," including the massive Manhattan District Project, which was transmuted in 1947

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[1] For postwar developments see Roger L. Geiger, *Research and Relevant Knowledge: American Research Universities Since 1940* (New York: Oxford Univ. Press, in press). For the prior period see Geiger, *To Advance Knowledge: The Growth of American Research Universities, 1900–1940* (New York: Oxford Univ. Press, 1986).

[2] Unless indicated, research and development data are from current volumes of the National Science Foundation series, *National Patterns of R&D Resources* (Washington, D.C.: Government Printing Office [GPO], annual).

[3] The "defense establishment" is defined by Harvey Brooks as the DOD, NASA, and the AEC, most of whose R and D activities relate to national security. These agencies are most similar in their patterns of dealing with industrial clientele and less so with respect to universities: "Nevertheless, the policies and the styles of these three agencies have been the largest shaping factor in the development of American science since the end of World War II." Brooks, "Impact of the Defense Establishment on Science and Education," in House Committee on Science and Astronautics, *Hearings on National Science Policy,* 91st Congress, 2nd session, 1970, pp. 931–963, quoting from p. 931.

into the AEC. The most significant new departure was the Office of Naval Research (ONR), which intended from the outset in 1945 to establish research relationships with individual scientists on university campuses. Some of the larger campus laboratories were also quick to begin the transition to permanent, peacetime research. Outside of support for the life science by the Department of Agriculture and NIH, the Department of Defense (DOD) and the AEC dominated support for academic research from V-J Day to Sputnik. Their combined total represented 96 percent of such funds in 1954 and 84 percent in 1958.[4]

Criticism of defense-related research was originally stimulated by considerations of foreign policy. The Union of Concerned Scientists was formed in 1945 largely to oppose the further development of nuclear weapons. Scientists were uncomfortable as well about the reliance of academic research on patronage by the armed services. In the last half of the 1960s opposition to military-supported research would once again be predicated on the international role of the United States. In between, though, consensus over the goals of the Cold War tended to preclude questioning the underlying premises of defense-related research. Instead, critics focused on the dysfunctional consequences of such support.

The principal concerns about the federally supported research economy can be conveniently grouped under the rubrics of dependence, domination, distortion, and displacement.[5] University officials worried considerably about how dependent certain departments had become on federal funds for research and graduate education. A cessation of this support—not likely, but a plausible fear at the time—would have crippled these endeavors and caused financial embarrassment to institutions. Private research universities, in particular, worried throughout the 1950s that this dependence could lead to federal domination. Only after Sputnik did the consensus change, so that federal support for academic science was interpreted as the foundation of a productive partnership.[6] This pair of anxieties largely concerned the institution; the latter pair—distortion and displacement—pertained more to the conduct of science. The development of certain scientific fields, it was commonly alleged, was distorted when the defense establishment chose the lines of research. Supporting so much programmatic research, moreover, meant that disinterested science based on disciplinary paradigms could be supplanted.

Such charges strike to the heart of how the postwar system affected the evolution of knowledge. Thus, besides alarming contemporaries, they have also intrigued historians of science. As the literature cited below will attest, historians have noted the total dependence of certain academic units on support from the defense establishment, and they have inferred that this implied domination (or cooptation) of institutions. They have also documented how defense support determined the problems that received solutions in specific fields, and have implied

[4] NSF, *Scientific Research and Development in Colleges, Universities: Expenditures and Manpower, 1954, 1958* (Washington, D.C., 1957, 1960); this figure excludes contract research centers. Cf. a similar reckoning by Paul Forman, "Behind Quantum Electronics: National Security as Basis for Physical Research in the United States, 1940–1960," *Historical Studies in the Physical and Biological Sciences* (*HSPS*) 1990, *19*:149–229, esp. pp. 188–200.

[5] Geiger, *Research and Relevant Knowledge* (cit. n. 1), Ch. 2.

[6] *Ibid.*, Ch. 7. See also President's Science Advisory Committee, *Scientific Progress, the Universities, and the Federal Government* (Washington, D.C.: GPO, 1960); and Charles V. Kidd, *American Universities and Federal Research* (Cambridge, Mass.: Harvard Univ. Press, 1959).

that, left to follow their own paradigms, academic scientists might well have extended knowledge in different directions.

The discussion that follows will not provide definitive answers to these charges, but rather will demonstrate that they represent a partial view of a very large phenomenon. How these issues are evaluated depends considerably upon where one chooses to look. Specifically, research relations between the defense establishment and academic science varied along two dimensions. Functionally, they served a variety of purposes, and these different purposes tended to assume different organizational forms in universities. The next three sections accordingly examine the nature of large university-affiliated laboratories; the pursuit of critical technologies, for the most part in special academic units; and "benign" support for unfettered basic research. While there was considerable continuity in these activities, they nevertheless changed over time, especially through accretion. Thus in the final section alterations in the relations between the defense establishment and academic science are analyzed for four relatively distinct periods. This second, temporal dimension illuminates how the defining characteristics and the direction of change varied over a quarter century. The categorizations employed are actually considerable simplifications of a far more complicated reality. They nevertheless seem necessary in order to move toward a more nuanced understanding of the impact of the defense establishment on the evolution of research universities and of science.

II. PATTERNS OF PATRONAGE: CONTRACT RESEARCH CENTERS AND NATIONAL LABS

Wartime contracts with universities for research and development were highly concentrated, with those institutions implicated in weapons development receiving by far the largest totals. Just six institutions received more than $10 million in contracts—Massachusetts Institute of Technology, California Institute of Technology, Harvard University, Columbia University, University of California at Berkeley, and Johns Hopkins University.[7] At four of them, wartime activities led fairly directly to major postwar contract research centers (discussed below). Harvard, having been the counterpart to MIT in investigating radar countermeasures, eschewed programmatic or classified research afterward; and Columbia housed significant portions of several lines of war research. The installations managed by Johns Hopkins and Caltech represented the most straightforward transition from wartime to peacetime military research; while developments at Berkeley and MIT were organizationally and intellectually more complex.

At federal contract research centers, by definition, military sponsors paid the full costs and determined the general objectives and work plans of the units. The universities, as contractors, provided managerial services. Internally, these centers resembled federal or industrial laboratories more than academic units, so that one might legitimately ask why they operated under university contracts at all. In fact, each center was a unique case. Different circumstances largely accounted for university affiliations.

[7] Total contracts, from the Office of Scientific Research and Development (OSRD) only, through 30 June 1945: James Phinney Baxter, *Scientists against Time* (Boston: Little, Brown, 1946), p. 456.

These arrangements carried certain advantages for the government. University management was probably less costly and more trustworthy than the other alternatives, and top scientists in particular usually preferred university settings. The centers were advantageous for universities as well. They cost nothing, brought handsome management fees, and also built up one particular facet of a university's research capability. The relationships between universities and weapons laboratories were nevertheless inherently problematic from the outset.

The Applied Physics Laboratory (APL) at Johns Hopkins was a case in point.[8] Its director, Merle Tuve, wanted the laboratory to be closely integrated with the university after the war in order to preserve the tight and fruitful coupling of science and technological development. The university could neither make such a financial commitment nor induce its departments to give academic appointments to the numerous APL personnel. Instead, an arms-length arrangement was worked out: the university gave APL scientists appointments in a new Institute for Cooperative Research on campus, but in return insisted that the laboratory avoid the actual production of weapons. The true nature of this relationship became apparent very soon afterward. The APL found it necessary to reassert control over the production of the guided missile system it had designed, and the university, with little leverage over the APL, had no choice but to acquiesce. Contract research centers danced to the tunes of their federal paymasters, not those of their nominal university managers.

Still, the contract research centers were not merely creatures of their military patrons. Clayton Koppes's history of the Jet Propulsion Laboratory (JPL) at Caltech reveals pervasive tensions on both sides of this relationship.[9] The JPL was justified to university trustees after the war for the usual reasons: it would uphold the international reputation of Caltech in the fields of aeronautics and jet propulsion; it would maintain at no cost a large base of scientific and engineering expertise; and it would conduct significant amounts of basic, unclassified science. All of this proved true, although the last point was sometimes in doubt. But the JPL in fact had little interaction with Caltech, and there was always a sizable faction among the faculty who regarded it as incompatible with the school's academic mission. The patrons—first the Army and then NASA—for their part found the relative independence of the JPL to be a source of intermittent irritation. Their attempts to assert greater control over the laboratory, just like similar efforts by Caltech, were partially effective at best. In the long run the institutional interests of the JPL itself prevailed. The laboratory preserved its special mission and its special status; and Caltech never seriously entertained the possibility of relinquishing its ties to the JPL in aeronautical and space sciences, nor of foregoing its management fee.

The incompatibility of the laboratories and their university sponsors was rooted in the highly applied nature of their work. The JPL, for example, harbored primarily an engineering culture, while that of Caltech was strongly scientific. At

[8] Michael Aaron Dennis, "Restructuring Technical Practice: The Johns Hopkins University Applied Physics Laboratory and the Massachusetts Institute of Technology Instrumentation Laboratory after World War II," typescript.

[9] Clayton R. Koppes, *JPL and the American Space Program: A History of the Jet Propulsion Laboratory* (New Haven: Yale Univ. Press, 1982).

the APL only about 5 percent of expenditures were regarded as basic research.[10] The classified nature of most research created a further barrier to academic links. The exceptions were the large particle accelerators funded by the AEC. At these facilities, which were classified among the National Laboratories, scientists conducted basic research, but they were supported for reasons that were scarcely disinterested. It was a truism of postwar science policy that the atomic bomb had been made possible by the fundamental discoveries of the interwar years. Postwar physicists invoked similar possibilities to justify their requests for large accelerators to probe the world of subatomic particles.[11]

E. O. Lawrence's Radiation Laboratory at Berkeley was always a special case among federal centers. Already a big-science facility supported by private funds before the war, it emerged in 1945 with the hardware for a large accelerator, experienced research teams, and the incomparable leadership of Lawrence himself. He quickly convinced General Leslie Groves to commit funds from the Manhattan Project toward launching a massive program of pure research in atomic physics.[12] These initiatives prompted East Coast physicists to request a facility of their own—the Brookhaven National Laboratory, managed by the Associated Universities, Inc. When the AEC assumed jurisdiction of these facilities in 1947, it thus found itself already committed to a large and expensive research program in particle physics.

Unlike the weapons-related centers, the Berkeley Radiation Laboratory—and Brookhaven National Laboratory as well—cultivated an open, academic mode of operation, at least to the extent possible given large expenditures, careful organization, team research, and security precautions. Also unlike the other centers, these AEC laboratories were extraordinarily fecund in generating basic scientific discoveries. As is well known, Lawrence and his laboratory were particularly prolific in this respect. With their head start in machines and research teams, the Berkeley physicists recorded a string of first accomplishments that merited them individually a like string of Nobel Prizes. The connection with the defense establishment and the consequent rationale for lavish federal support, however, were never lost sight of by Lawrence himself. With the onset of the Cold War and the Soviet atomic challenge, he rededicated the laboratory to assuring American nuclear superiority. This emphasis led to the development of a second laboratory at Livermore devoted to military projects. Classified research accordingly migrated from Berkeley to Livermore. Until 1971 the latter existed as a branch of the Radiation Laboratory; since then it has been a separately administered center.[13]

In most respects the research performed at JPL, APL, and smaller centers with

[10] Koppes, *JPL*, p. 240; and Dennis, "Restructuring Technical Practice."

[11] Robert W. Seidel, "Accelerating Science: The Postwar Transformation of the Lawrence Radiation Laboratory," *HSPS*, 1983, *13*:375–400, esp. pp. 382–383; and Seidel, "A Home for Big Science: The Atomic Energy Commission's Laboratory System," *HSPS*, 1986, *16*:135–175.

[12] John Heilbron and Robert W. Seidel, *Lawrence and His Laboratory: A History of the Lawrence Berkeley Laboratory*, Vol. I ((Berkeley: Univ. California Press, 1990); Seidel, "Accelerating Science," pp. 379–384; and John Heilbron, Robert W. Seidel, and Bruce R. Wheaton, *Lawrence and His Laboratory: Nuclear Science at Berkeley, 1931–1961* (Berkeley: Univ. California Office for History of Science and Technology, 1981).

[13] Herbert F. York, *Making Weapons, Talking Peace: A Physicist's Odyssey from Hiroshima to Geneva* (New York: Basic Books, 1987), pp. 65–78; and Seidel, "Home for Big Science" (cit. n. 11), pp. 151–156.

similar pedigrees scarcely deserves to be classed with academic science. It represented for the most part contract research by professional staff for specific defense-related purposes. The laboratories were generally located off-campus and access was restricted. The topics investigated were germane to a handful of faculty and advanced graduate students at best, and the classified nature of much research placed it outside of academic channels of communication. The centers thus had a limited impact on the academic development of those campuses. The Radiation Laboratory at Berkeley, however, was a different story. Not only were the basic discoveries made there of monumental importance to atomic physics, but the laboratory was a major factor in elevating the academic standing of the university. First, Lawrence spawned major scientific enterprises in distant fields. He launched Melvin Calvin, for example, on the investigations that resolved the chemistry of photosynthesis. Second, the very accomplishments of the atomic physicists were a goad to higher standards of attainment across the entire campus.[14]

III. CRITICAL TECHNOLOGIES, CRITICAL DEPARTMENTS

While federal contract research centers were a distinct, although shifting, legal category, other large units performed research of similar character for the defense establishment without being so designated: for example, the Willow Run Laboratories of the University of Michigan, the Cornell Aeronautical Laboratories in Buffalo, and the Instrumentation Laboratory of Charles Stark Draper at MIT. A continuum might thus be pictured, extending from the weapons-oriented centers at one extreme to academic departments engaging in only basic research at the other. In between one would find academic departments, or parts thereof, that were largely built upon close relationships with elements of the defense establishment. Often these departments were related to research institutes (under various appellations) where highly programmatic research, basic or applied, was performed. Such departments are central to any interpretation of the interaction of the defense establishment and the postwar academic research system. They operated in fields that were crucial for the technologies of the supporting agencies. The influence of research support consequently tended to shape and define those fields. Thus the issues of the distortion and displacement of academic research by defense-based support are most germane in these areas. The research patrons, however, did not act alone. Professors and administrators at times eagerly exploited the opportunities presented by these critical technologies to build research empires for their departments or institutions.[15]

In a host of academic fields—aeronautical and nuclear engineering, optics, underwater acoustics, space science—miltary interests and deep pockets simply

[14] Melvin Calvin, "Chemistry and Chemical Biodynamics at Berkeley, 1937–1980," oral history (History of Science and Technology Program, Bancroft Library, Univ. California, Berkeley, 1984); and Geiger, *Research and Relevant Knowledge* (cit. n. 1), Ch. 3.

[15] The well-known cases are discussed below, but see also Peter Galison, "Physics between War and Peace," in *Science, Technology, and the Military,* ed. E. Mendelsohn, M. Smith, and P. Weingart (Dordrecht/Boston: Kluwer, 1988), pp. 47–85 (esp. for Harvard and Princeton); and Rebecca S. Lowen, "Transforming the University: Administrators, Physicists, and Industrial and Federal Patronage at Stanford, 1935–1949," *History of Education Quarterly,* 1991, *31*:365–388.

overwhelmed considerations of pure science or domestic applications.[16] James A. Van Allen, for example, found the APL to be a fairly uncongenial setting for conducting basic research on the upper atmosphere. Moving to the University of Iowa in 1950, he found that even on campus, collaboration with the defense establishment was the only possible course for establishing a viable research program.[17] In aeronautics the combined leverage of the Pentagon and their industrial clients predominated heavily. According to Stuart Leslie, the department of aeronautical engineering at Stanford became a virtual adjunct of Lockheed and its missile program.[18]

Military needs and academic science interacted most densely in the multidimensional field of electronics.[19] This interaction has been documented most thoroughly at MIT and Stanford. The enormous wartime establishment of radar research at MIT established a large stake in this field that the Institute made sure it would not relinquish. Stanford, in contrast, was a late developer, but electronics provided the crucial wedge for enlarging its niche in the research system and ultimately raising its academic standing.

MIT's Research Laboratory of Electronics (RLE) was created to continue the wartime study of phenomena associated with microwave radiation.[20] It soon received an exceedingly liberal contract from the joint services (ONR, the Air Force, and the Signal Corps) that provided annual support of $600,000 to be used as RLE saw fit for basic research and graduate education. In return, the services wished "to maintain close liaison between the military and the frontiers of electronic science and engineering" and to have "a laboratory from which the military services can draw competent technical help at critical times . . . a research facility that can grow rapidly to meet a specific need."[21] The RLE grew prodigiously as both a locus for frontier research and an asset to the military services.

The services utilized their access to RLE soon and repeatedly for assistance with military projects. From the outset the joint-services contract was supplemented by the continuation of some classified research from the wartime radar

[16] A statement of ONR research policy in 1954 made a distinction between critical fields for naval technology: some had "limited interest for exploitation to other components of the nation's [scientific] community," examples being oceanography, explosives chemistry, numerical analysis, fluid mechanics and research on the Arctic or upper atmosphere. Other fields were "at the same time of great significance to industry and other components of society," namely, solid-state physics, statistics, microbiology, physiological psychology, electrochemistry, and meteorology. See E. Piore, "ONR Research Policy," *Naval Research Reviews,* April 1954, pp. 11–12; quoted in S. S. Schweber, "The Mutual Embrace of Science and the Military: ONR and the Growth of Physics in the United States after World War II," in *Science, Technology, and the Military,* ed. Mendelsohn, Smith, and Weingart (cit. n. 15), pp. 3–46, on p.23.

[17] Dennis, "Restructuring Technological Practice" (cit. n. 8); and Allan A. Needell, "Preparing for the Space Age: University-based Research, 1946–1957," *HSPS,* 1990, *18*:89–110, esp. pp. 100–106.

[18] Stuart W. Leslie, "The Military and the Shaping of University Teaching and Research," paper presented to the Workshop on Research Perspectives on Research Universities, Pennsylvania State University, 14–15 April 1989.

[19] Forman, "Behind Quantum Mechanics" (cit. n. 4).

[20] *R.L.E.: 1946 + 20* (Cambridge, Mass.: Research Laboratory of Electronics, 1966); Karl L. Wildes and Nilo A. Lindgren, *A Century of Electrical Engineering and Computer Science at MIT, 1882–1982* (Cambridge, Mass.: MIT Press, 1985), pp. 242–279; Stuart W. Leslie, "Profit and Loss: the Military and MIT in the Postwar Era," *HSPS,* 1990, *21*:59–85, esp. pp. 60–66; and Geiger, *Research and Relevant Knowledge* (cit. n. 1), Ch. 3.

[21] Quoted in Henry J. Zimmerman, "Research and Education," in *R.L.E.,* pp. 17–21.

projects. But soon the services had new needs to meet. In 1946 the Navy requested that the RLE develop a guidance system for the Meteor missile. According to one participant, "after much soul-searching, it was recognized that this was, indeed, an advanced engineering project, that both applied research and advanced development were required in its execution, and that it had many attractive features for engineering pedagogy." Perhaps this was the case, but MIT could scarcely say no to one of the RLE's principal sponsors. This pattern would become familiar: ingrained patriotism and plausible rationalizations would invariably lead to the acceptance of military programs. The RLE thus constituted one of the central knots in a tangled skein of relationships between MIT and the military.[22]

The outbreak of the Korean War created conditions for increased military utilization of the RLE, as foreseen in the original agreement. In 1950 the Pentagon asked RLE to double its budget in order to accommodate applied military research projects. Part of this additional work was connected with the beginning of an Air Force effort to design and build an early-warning strategic radar system. At the same time, an ad hoc group (Project Charles) was formed to consider the feasibility of this project and the desirability of MIT's undertaking it. The dimensions of this endeavor proved so massive that the creation of a separate organization was recommended. Accordingly, in 1951 the Lincoln Laboratory was established as a federal contract laboratory administered by MIT. Many of the military research projects at RLE were then transferred to the Lincoln Laboratory; in fact, the RLE director moved there as well. No conflict of institutional cultures existed here. In many ways the two laboratories were joined in a single effort. Some graduate students pursued research at Lincoln, and Lincoln staff earned advanced degrees at the Institute. Between them, RLE and Lincoln spawned some sixty electronics firms, and Lincoln also became an ongoing sponsor of RLE research projects.[23]

The segregation of military hardware development from more academic kinds of research nevertheless helped to preserve the special qualities of the RLE. For some time thereafter the preponderance of support came from the joint services contract and was allocated at the discretion of the director. Over time, specific projects became a larger part of the budget and the work, but the latitude allowed by the basic contract was the key to the intellectual dynamism of the RLE. Individual lines of inquiry progressed, branched, or intertwined. Five distinct research groups existed at the RLE in 1946, ten in 1951, twenty-two in 1956, and thirty in 1961. By this last date eighteen of those groups belonged to a separate Division of Communication Sciences and Engineering (established in 1958) that had evolved from just one of the 1946 groups.[24] MIT's extensive commitment to serving the defense establishment in no way precluded the achievement of academic distinction. At Stanford, on the other hand, service was seen more as a means of building academic prestige.

The academic rise of Stanford is indelibly associated with the career of

[22] Albert G. Hill, "Why the Military?" in *R.L.E.*, pp. 7-11 (quoting from p. 9); and James R. Killian, *The Education of a College President: A Memoir* (Cambridge, Mass.: MIT Press, 1985), pp. 63-67.

[23] Leslie, "Profit and Loss" (cit. n. 20), pp. 66-70; Hill, "Why the Military?" and Killian, *Education*, pp. 71-73.

[24] Geiger, *Research and Relevant Knowledge* (cit. n. 1), Ch. 3.

Frederick E. Terman, who was dean of engineering (1945–1955) and then provost (1955–1965). During the war Terman had interrupted a lifetime at Stanford to work on radar countermeasures at Harvard. He emerged from that experience with great admiration for the academic esteem and self-assurance of Harvard, but also a realization that Stanford would have to serve research patrons, much like MIT, in order to emulate Harvard's academic prestige.[25]

The building of postwar research at Stanford began modestly, but early, in January 1945, with an authorization to establish a microwave laboratory to exploit a prewar invention, the klystron.[26] In 1946 ONR began awarding contracts for such work, and the following year additional contracts for military-sponsored research were consolidated into the Stanford Electronics Research Laboratory. By 1950 Stanford was performing almost $500,000 of electronics research for the Department of Defense—about one quarter of the university's total research expenditures. At this juncture the Korean War greatly expanded these activities. When the Navy dangled the prospect of large contracts for classified, applied research in this area, Terman felt that Stanford could not refuse. Stanford had achieved a research program in electronics second only to that of MIT; to allow these research contracts to go elsewhere, he told President Wallace Sterling, would mean forfeiting that position. Accordingly, Stanford added the Applied Electronics Laboratory, which was soon conducting over $1,000,000 of research by itself.

The two electronics laboratories were soon merged into the Stanford Electronics Laboratories. Classified or no, Stanford engineers felt that their work in electronics involved fundamental scientific questions and was closely integrated with the academic mission of the university. This contention reflected the reality of the particular scientific territory they were exploring—the interstices of physics and electrical engineering. Building more powerful and sophisticated microwave tubes may have solved important problems for the Navy, but it also contributed to the linear electron accelerator with which Robert Hofstadter earned a Nobel Prize by exploring the interior of the atom. This same matrix of research yielded the Nobel Prize–winning work of Felix Bloch on nuclear magnetic resonance, as well as the equipment that made possible UHF television broadcasting. Electronics research at Stanford created capabilities for path-breaking fundamental research while also retaining the engineering nexus between science and technology. But while examples like these suggest a happy conjuncture of military and academic purposes, they do not reveal whether such situations were the exception or the rule.

There can be little doubt that the interests of the defense establishment in critical technologies profoundly affected the development of those fields. Paul Forman has detailed the enormous investment in defense electronics during the

[25] Frederick Emmons Terman, oral history (History of Science and Technology Program, Bancroft Library, Univ. California, Berkeley, 1984); and Geiger, *Research and Relevant Knowledge,* Ch. 5.

[26] For the development of electronics at Stanford see Stuart W. Leslie and Bruce Hevly, "Steeple Building at Stanford: Electrical Engineering, Physics, and Microwave Research," *Proceedings of the IEEE,* 1985, *73*:1169–1180; Stuart W. Leslie, "Playing the Education Game to Win: The Military and Interdisciplinary Research at Stanford," *HSPS,* 1987, *18*:55–88; and Rebecca Lowen, " 'Exploiting a Wonderful Opportunity': Stanford University, Industry, and the Federal Government" (Ph.D. diss., Stanford University, 1990).

1950s, concluding that concentration on "military problems effectively rotated the orientation of academic physics toward techniques and applications." Nuclear engineering at MIT, according to Stuart Leslie, produced advances in precisely what the military establishment was supporting—specifically, "reactor technology for submarine propulsion, plutonium production, and other specifically military applications." Peter Galison viewed the alliance between physicists and the miltary as the source for a new human architecture—based on large laboratories and team research—for university physics.[27] It can be argued, furthermore, that the knowledge demanded by military patrons permeated the curriculum, classroom, and textbooks of these subjects.[28] Yet not all commentators are convinced that these effects were pernicious. Harvey Brooks, writing at the beginning of the 1970s, found it "hard to make a strong case that government science support, let alone defense support, has distorted university research to a significant degree." With a longer perspective, Dan Kevles still viewed the opposition of pure and applied physics inherent in critical views as an unrealistic simplification of the history of physics research: "In the first decade of the Cold War, physics diversified into intellectually promising areas made hot by the needs of national security." In the process, certain subjects managed to "take on lives of their own as intellectually compelling areas of inquiry."[29]

When the discussion of this topic is focused solely on technologies critical to the defense establishment, a narrow and somewhat misleading picture results. At least two further dimensions need to be taken into account. First, a more benign role was filled through support for universities and basic science that transcended the near-term technical needs of the defense agencies. Second, the contours of the relationship between academic science and the defense establishment changed considerably over time. These two topics will be considered in the following sections.

IV. DEFENSE ESTABLISHMENT SUPPORT FOR BASIC ACADEMIC SCIENCE

For the defense agencies two basic rationales dictated maintaining links with academic science. Their direct interests in critical technologies largely accounted for the contract research centers and the extensive support of departments in critical fields. The second rationale, however, was posited on maintaining access to basic academic research and the scientists conducting it. This fundamental need for access can be broken down, somewhat artificially, into four considerations. First, basic research and applied research or development are inherently complementary. Applied activities depend in numerous and unpredictable ways upon areas of fundamental research. Thus a degree of contact with basic research seems nec-

[27] Forman, "Behind Quantum Electronics" (cit. n. 4), p. 216; Leslie, "Profit and Loss" (cit. n. 20), p. 78; and Galison, "Physics between War and Peace" (cit. n. 15), pp. 79–80. This last point is also made by Schweber, "Mutual Embrace" (cit. n. 16), on pp. 8, 35–36.

[28] Leslie, "Profit and Loss," p. 69; and Carl Barus, "Military Influence on the Curriculum Since World War II," *Technology and Society Magazine,* June 1987, pp. 3–9.

[29] Brooks, "Impact of the Defense Establishment" (cit. n. 3), p. 948; and Dan Kevles, "Cold War and Hot Physics: Science, Security, and the American State, 1945–56," *HSPS,* 1990, *20*:239–264, on pp. 264, 262.

essary merely to "know what questions to ask and what the answers mean."[30] Interestingly, the figure of 5 percent of total R and D in technological enterprises devoted to basic research seems to recur in the literature.[31] In any case, the more R and D an enterprise conducts, the greater the need for broad contact with basic research. Far wider coverage at less cost can be achieved through contact with academic scientists in the field. Second, since academic scientists may be needed for advice and consultation, and the most effective contact is person to person, it is desirable to maintain direct relationships with them. Third, nonacademic research agencies chiefly look to universities to furnish scientific manpower. Defense agencies, with continual needs for scientists, recruited graduates through ongoing relations with their mentors. The fourth consideration shades into the concerns about the steering of academic science. Defense agencies wanted academic scientists to be engaged with problems related to agency missions. Thus some support represented conscious attempts to stimulate particular fields. Regardless of which of these considerations might have been uppermost in any given case, in defense agency access to university research the interests of patrons and those of scientists largely coincided. Moreover, such support played a large role in the postwar development of university research.

Cultivating ongoing working relationships with academic scientists was a high priority for ONR after the war.[32] ONR was inspired partly by the idealism toward research prevailing at the end of the war and partly by the Navy's special need to catch up in the area of nuclear physics. (Some 40 percent of early ONR grants went to support nuclear physics, a burden the office would later share with the AEC.) In the fall of 1945 ONR officers visited campuses to convince scientists and university administrators of the advantages of doing research for the Navy. To secure cooperation the Navy was willing to assist the research needs of universities and to respect academic styles of research. The problem of contracting for research with unforeseeable results was overcome by devising a single comprehensive university contract to which specific projects could be appended as task orders. ONR also agreed that the research they funded would be unclassified and publishable. Most significant of all, ONR allowed the investigators themselves to initiate proposals. If a proposal was considered to be sound and of interest, ONR would support it without restriction or interference. The anticipated campus opposition to military-supported research never materialized. The leading research

[30] This view has been chiefly applied to industrial utilization of research: see Roger L. Geiger, "The Ambiguous Link: Private Industry and University Research" in *Higher Education and Economic Development,* ed. William E. Becker and Darrell Lewis (Dordrecht/Boston: Kluwer, 1992); Richard R. Nelson, "What is Private and What is Public about Technology," *Science, Technology, and Human Values,* 1989, *14*:229–241; and David C. Mowery and Nathan Rosenberg, *Technology and the Pursuit of Economic Growth* (New York: Cambridge Univ. Press, 1989). ONR explicitly referred to this type of access as "listening post activity": Schweber, "Mutual Embrace" (cit. n. 16).

[31] Michael Dennis notes that basic researchers at the early APL were called the "five-percenters": "Restructuring Technical Practice" (cit. n. 8). Forman emphasizes this "rule of the twentieth," explaining that it "results not from any intrinsic quantitative dependence of technical development upon 'basic' research, but because a twentieth is the highest still inappreciable rate of taxation on social investment in advanced technological enterprise": "Behind Quantum Electronics" (cit. n. 4), pp. 198–199). However, U.S. industry currently does expend 5 percent of its R and D funds on basic research: NSF, *National Patterns of R&D Resources* (cit. n. 2) (1989), pp. 43, 45.

[32] Harvey M. Sapolsky, *Science and the Navy: The History of the Office of Naval Research* (Princeton: Princeton Univ. Press, 1990); and Schweber, "Mutual Embrace" (cit. n. 16), pp. 15–24.

universities—Harvard, Chicago, California, Caltech, and MIT—quickly signed ONR contracts, and the die was cast. The result of these efforts was that ONR emerged as the ideal patron of science, "the example always to be cited" for enlightened research patronage.[33]

ONR was structured so that the Navy could rely upon civilian scientists to exercise authority over the content of research. Its top civilian post of Chief Scientist was filled by Alan T. Waterman, who came via the Office of Scientific Research and Development (OSRD) and the Yale physics department. The foremost organizational leaders of American science were recruited for a blue-ribbon Naval Research Advisory Committee. Twelve specialized advisory panels, containing another 125 scientists, helped ONR to evaluate proposals. Because of its abundant funds, ONR was able to begin supporting large amounts of research almost immediately after the war ended. When it received legislative authorization (August 1946) ONR had already let $24 million in contracts, which included 602 academic research projects involving 4,000 scientists and graduate students. ONR thus quickly became the principal supporter of research in science departments. For the rest of the 1940s it provided approximately $20 million annually for university research. By this juncture ONR was supporting one quarter of the proposals it received. Still, it managed to fund 1,131 projects in 200 institutions. Moreover, unlike the majority of agencies channeling funds from the defense establishment, ONR funded small rather than big science. Most of its contracts fell in the range of $12,000 to $40,000 and ran for less than a year.[34] As a patron of research the ONR sought to please as many as possible of its university supplicants.

Harvey Sapolsky, the historian of ONR, has pointed out that the agency's "golden age" lasted just four years—from 1946 to 1950. During that time it enjoyed considerable autonomy within the Navy bureaucracy and was also able to posture as the protector of academic science in the absence of a national science foundation. After 1950, however, ONR had to cope with increasing pressures for relevance to naval needs. It nevertheless continued to play a substantial role in supporting fundamental academic research. ONR supported more university research than NIH until the Shannon era, and more than NSF until after Sputnik.[35] By then another component of the defense establishment was eager to win the good will and collaboration of academic scientists.

NASA, as a new scientific agency with a huge mission, had an imperative need to expand relations with academic science. The mandate of sending men to the moon and back required additional knowledge on a myriad of topics, from behavioral biology to planetary science. In addition, this huge engineering effort would claim up to 5 percent of the nation's total scientific manpower. As a latecomer to the university research system, NASA had to purchase its access to top-quality science.

The chief means through which NASA sought to establish links with academic

[33] Harvey M. Sapolsky, "Academic Science and the Military: The Years since the Second World War," in *The Sciences in the American Context: New Perspectives,* ed. Nathan Reingold (Washington, D.C.: Smithsonian Institution Press, 1979), pp. 379–399, on p. 386.

[34] ONR expenditures are given in Sapolsky, *Science and the Navy,* p. 132; and Geiger, *Research and Relevant Knowledge* (cit. n. 1), Ch. 1.

[35] Sapolsky, *Science and the Navy,* pp. 57ff.

Table 1. University Science Development Programs of the 1960s

Agency	Program	Years	Funds expended	Institutions supported
NASA	Sustaining University	1962–1971	$221,473,000	175
NSF	University Science Dev.	1965–1971	179,590,000	32
NSF	Special Science Dev.	1966–1971	11,937,000	11
NSF	Departmental Sci. Dev.	1967–1971	42,688,000	62
DOD	Project THEMIS	1967–1971	94,490,000	82
NIH	Health Science Advancement	1966–1974	26,250,000	11
	Total		$576,428,000	216

SOURCE: National Science Foundation, *The NSF Science Development Programs: A Documentary Report* (Washington, D.C.: NSF, 1977).

science was the "Sustaining University Program."[36] This program supplied institutional support in the general area of space-related science and engineering—grants for the training of graduate students and construction of research facilities, and unrestricted funds for research. From 1963, when NASA became a major supporter of university research, through 1967 the Sustaining University Program comprised a third of all NASA obligations to universities—almost $40 million per year (still, less than one percent of NASA's budget!). The remainder of its support was for R and D closely related to specific projects. After 1967 support to universities went almost exclusively for such project research. But all told, from 1962 to 1971 the Sustaining University Program disbursed over $220 million to more than 170 colleges and universities.

NASA's Sustaining University Program was the first federal science development program to be implemented. During the 1960s six such programs were designed to enlarge the base of academic research by providing institutional aid to second- or third-tier universities. Such grants were generally made to bolster specific departments, thereby developing active centers of research that would, presumably, encourage more research throughout the institution. NSF had sought such a program earlier but was only able to launch the first of three programs in 1965, when the geographical dispersion of research support became an avowed government policy. NIH, which provided substantial institutional aid through its regular programs, launched a limited science development program in 1966. The Department of Defense was initially reluctant to make such an effort, but did an about-face in starting Project THEMIS in 1967.[37] Through this program the DOD distributed $94 million to 82 institutions, almost all of which were medium to minor performers of federal research. The NASA and DOD programs together granted 55 percent of federal science development funds (see Table 1).

The science development programs, with each of four agencies pursuing the same general objective in its own distinctive way, typified American science policy in an era of abundance. It undoubtedly contributed to the enlargement of uni-

[36] Geiger, *Research and Relevant Knowledge,* Ch. 6; and Homer E. Newell, *Beyond the Atmosphere* (Washington, D.C.: NASA, 1980), pp. 223–237.

[37] Geiger, *Research and Relevant Knowledge,* Ch. 7. The AEC, whose contracts usually made provision for the needed research capacity, did not sponsor a science development program.

versity research. The contributions of the defense establishment clearly made this program far larger than it otherwise could have been. This outcome, however, underscores a deeper point. The benign role of the defense establishment in sustaining and enlarging the scientific enterprise in universities continued long after the "golden age" of ONR. Throughout the 1950s and 1960s substantial funds from these agencies continued to flow to the investigation of fundamental topics, the provision of research equipment and facilities, and the training of future scientists and engineers. The conclusion reached by Harvey Brooks thus seems inescapable: "It is unrealistic to argue that the [1970] base of support could have been achieved without the efforts of the military or without the stimulus of the Cold War."[38] Support from the defense establishment may have distorted university research, but the absence of such support without question would have produced a greater "distortion"—in that it would have remained a far smaller enterprise.

It is also probably unrealistic to assume that benign forms of support might have still been extended to universities in the absence of the heavily programmatic support for centers and critical technologies. Some exceptions aside, if all programmatic research had been incorporated into government laboratories, much of the basic research associated with it would have been brought in house as well. With a much diminished stake in academic science, the defense establishment would have had little reason to make substantial investments in it, to invigorate it, or to interact with it. To some extent, as contract research was brought in house after 1970, the defense establishment did reduce ties to academia.

V. STAGES IN THE EVOLUTION OF DEFENSE TIES WITH ACADEMIC RESEARCH

Both change and continuity have characterized the postwar university research system. Institutional structures have on the whole exhibited considerable longevity; for many of the wartime and postwar creations, half-century anniversaries loom. The content of the science performed has naturally evolved according to its own dynamics—branching or mutating into ever-changing subfields in some cases, in others remaining within channels fixed by the nature of missions and machines. This relentless activity has taken place within a relationship that has been subject to a dynamic of its own. Here, however, a definite pattern is discernible. In the immediate aftermath of the war, universities and university scientists dealt with the defense establishment on advantageous terms. With the onset of the Cold War, and especially the Korean War, far-reaching claims were made by these patrons upon the relationship so deliberately cultivated. Conditions changed once again with the Soviet launch of Sputnik. In an all-out scientific and technological race, academic scientists were once more valued and sought after. This relationship soured later in the 1960s under increasingly virulent attacks from opponents of the military on campus. The tension was finally resolved by the Mansfield Amendment—in some ways a formal act of separation. The relationship between the defense establishment and academic institutions that was born in World War II thus passed through four distinct phases before reaching its denouement a quarter century later.

[38] Brooks, "Impact of the Defense Establishment" (cit. n. 3), p. 945.

The Golden Age of ONR, 1945–1950

Viewed in isolation, ONR often appears as the sole enlightened patron of academic science to emerge from World War II. Such an outlook, however, is misleading. Rather, ONR expressed in a liberal or even extravagant manner the essential features of defense-university relations under immediate postwar conditions. With the cessation of hostilities, the crucial consideration was no longer the specific scientific projects used to fashion technologies of war, but rather the scientists who held the key to the technology of future wars. Most leading scientists, however, were eager to return to university campuses. The young naval officers who organized ONR grasped the logic of this situation and aggressively set about establishing contracts with major universities. Elsewhere in the military, the same logic took somewhat longer to penetrate.

In the spring of 1946 Army Chief of Staff General Dwight D. Eisenhower circulated a memo, "Scientific and Technological Resources as Military Assets," which identified a permanent need for the Army "to support broad research programs in educational institutions."[39] It was at this time that the Joint Services contract with MIT provided the RLE with open-ended support. The following year a triservice grant to Stanford laid the foundation for the Electronics Research Laboratory. In both institutions the scientists had broad academic freedom to pursue research at the frontiers of their fields, and both laboratories were hugely productive in both scientific and military research.[40] ONR also had a role in both these endeavors, and it developed cooperative programs with the AEC as well. By the late 1940s it was administering significant amounts of transfer funds for university research from other agencies. It scarcely mattered, then, that the other services remained heavily programmatic in their ties with university research, since the influence of ONR extended beyond the Navy.[41]

In the field of atomic energy it was quickly apparent that arrangements would have to be made with scientists in their university locales. Scientists had fled the wartime labs, leaving behind depleted staffs, low morale, and deteriorating programs. Los Alamos, for example, held an extensive program in 1946 to persuade university scientists to maintain research ties.[42] General Groves nevertheless had already concluded early that year that an extensive research program would be needed to sustain the military's stake in atomic energy. A committee of civilian scientists recommended sponsorship of fundamental, unclassified research in universities and special laboratories. The commitments to Berkeley were soon supplemented by the decision to build the Brookhaven laboratory.[43]

When the AEC assumed responsibility for this field, it was initially quite

[39] Reprinted in Seymour Melman, *Pentagon Capitalism: The Political Economy of War* (New York: McGraw-Hill, 1970), pp. 231–234.

[40] Leslie, "Profit and Loss" (cit. n. 20), pp. 64–66; and Leslie, "Playing the Education Game" (cit. n. 26), pp. 68–69.

[41] Sapolsky notes that ONR proposed taking over the sponsorship of all basic research for the armed services but was rebuffed by the Research and Development Board: *Science and the Navy* (cit. n. 32), p. 52.

[42] Richard G. Hewlett and Francis Duncan, *Atomic Shield, 1947–1952* (University Park: Pennsylvania State Univ. Press, 1969), pp. 33–35; and Manhattan District History, *Project "Y": The Los Alamos Story* (Los Angeles: Tomash, 1983), pp. 380–429.

[43] Allan A. Needell, "Nuclear Reactors and the Founding of the Brookhaven National Laboratory," *HSPS,* 1983, *14*:93–122; and Seidel, "Home for Big Science," (cit. n. 11), p. 140.

timid in funding university research. Congress had expressly withheld authority for making grants, and the national laboratories seemed a sufficiently taxing commitment. The AEC was inexorably drawn, however, into supporting growing amounts of basic research in universities. Already in 1947 three sources of pressure were evident. The scientists upon whom the AEC depended for strategic guidance strongly favored academic support. In particular, J. Robert Oppenheimer, chairman of the General Advisory Committee, argued that AEC support for basic research should be geared to the capacity of university research teams rather than to purely internal needs. The commission's monopoly over radioactive substances had profound implications for biology, both in the utilization of tracer isotopes and for cancer research. A new division of biology and medicine began supporting university research early in 1948, enriched by a congressional authorization to expend $5 million for cancer research. The ONR in 1947 requested that AEC share the burden of supporting the program it had launched in nuclear physics. After mulling over the decision for a year, it agreed. When Kenneth Pitzer, a Berkeley chemist, became the director of research at AEC in 1948, it was understood that closer relations with universities would be cultivated.[44]

The postwar rapprochement between universities and the defense establishment was not solely the result of initiatives from the government side. Academic scientists during the war had experienced big science with ample support, and they had no intention of reverting to the scientific *status quo ante bellum.* In the hiatus between wartime and peacetime organization, the scientists themselves took the initiative in launching major undertakings. The University of Chicago organized a new Institute for Nuclear Studies in conjunction with the Argonne laboratory; Lawrence quickly began expanding his laboratory with Manhattan Project funds; MIT used its own seed money to launch the Research Laboratory of Electronics; Stanford did much the same before Terman garnered large ONR support; and Eastern physicists, led by Isidor I. Rabi, succeeded in winning the Brookhaven National Laboratory for their region.[45] It would be difficult to maintain that these and other academic scientists were being exploited or used; they sought and utilized resources for research that they wished to perform. The situation changed, however, by 1950, when the threat to national security caused the defense establishment to start cashing in its investment in academic research.

The Cold War and Korea, 1950–1957

The onset of the Cold War in Europe, the victory of Communist forces on mainland China, the Soviet detonation of an atomic device, and finally the invasion of South Korea—these events galvanized the United States into a massive rebuilding of military capabilities. Accompanying this effort was a mobilization of research as well. For a time creating another version of OSRD was contemplated, but such a step was scarcely needed. An infrastructure of scientists working on defense-related problems and a network for contacting them were already in

[44] Hewlett and Duncan, *Atomic Shield* (cit. n. 42), pp. 79–83, 222–227.
[45] Seidel, "Accelerating Science"; Needell, "Nuclear Reactors"; Leslie, "Profit and Loss"; and Leslie, "Playing the Education Game" (works cit. nn. 11, 43, 20, 26).

place. Only money and direction were required to initiate or expand those activities most relevant to national security. Each of the laboratories mentioned in the previous paragraph was directly affected. RLE undertook the expansion of effort that led to the founding of the Lincoln Laboratory. Stanford added the Applied Electronics Laboratory. At Berkeley, Lawrence diverted greater attention to military projects, a development that soon produced the Livermore laboratory. The Argonne laboratory, by now heavily devoted to reactor development, readily adjusted to military priorities; Brookhaven, where the emphasis was predominately on basic research, was the most lightly touched.[46]

This sharp escalation of narrowly programmatic research has been documented and analyzed in recent articles by Paul Forman and Dan Kevles. Forman argued that physics research was distorted from basic to applied topics and that scientists were thus "used" by the defense establishment. Kevles refused to classify physics research into invidious categories, but found the negative effects on physicists to be more insidious, in that they acquired a vested interest in the arms race and the Cold War.[47] The conflict generated by military sponsorship of research is not merely a matter for historical argument, but rather something that affected the perceptions of contemporaries.

Some of the foremost leaders of the nation's research system voiced public criticism of military domination at precisely this juncture. President Lee Dubridge of Caltech hoped that academic research would free itself from being a stepchild of the military. Julius Stratton worried that the large volume of military research was warping the nature of universities. President James Conant of Harvard warned that university research was becoming too programmatic. Merle Tuve echoed both Stratton's and Conant's concerns, lamenting that universities seemed to be behaving like industrial corporations.[48] Alan Waterman used the fledgling NSF as bully pulpit for the view that academic research should consist predominantly of disinterested, fundamental investigations, not beholden to military ends.

On the other side of this relationship, the miltary patrons assumed a far more critical stance toward supporting basic academic research than they had immediately after the war. From 1950 onward, Harvey Sapolsky reports, ONR was under continual pressure to justify its patronage in terms of relevance to naval needs.[49] When Charles E. Wilson became Secretary of Defense, he not only ridiculed basic (or "pure") research, but also sought to slash its support. The AEC during these

[46] Hewlett and Duncan, *Atomic Shield* (cit. n. 42), pp. 433, 486, 500; Leslie, "Profit and Loss"; and Leslie, "Playing the Education Game."

[47] Forman, "Behind Quantum Electronics" (cit. n. 4), esp. pp. 150, 216, 224–229; and Kevles, "Cold War and Hot Physics" (cit. n. 29), esp. pp. 262–264.

[48] Lee A. Dubridge, "National Science Foundation Act," *Bulletin of the Atomic Scientists*, 1950, *6*:162; Julius A. Stratton, "Research and the University," *Chemical and Engineering News*, 1953, *31*:2581–2583; James B. Conant, *Science and Common Sense* (New Haven: Yale Univ. Press, 1951), 323; and Merle A. Tuve, "Technology and National Research Policy," *Bull. Atomic Sci.*, 1953, *9*:290–293.

[49] Sapolsky, *Science and the Navy* (cit. n. 32), pp. 57–58, 52. Schweber documents a pervasive effort by a new generation of officers "to regain control over all aspects of weapons research and development, control that had been taken from them by OSRD during the war": "Mutual Embrace" (cit. n. 16), p. 9.

years greatly expanded work within its national laboratories, while conceding only minor additions to academic research.[50]

While a certain degree of turmoil surrounded support for academic research, a larger process of accretion was in fact taking place. In the initial postwar period benign support for academic research from ONR and the AEC was superimposed on a wartime research system that, in the case of JPL, APL, and similar facilities, continued to function. After 1950 the acceleration of military research superimposed another layer on this system—activities of a generally applied nature intended to contribute specifically to national defense. This bundle of projects was particularly heavily weighted toward electronics and revolutionized that field in fairly short order. Contemporaries conventionally spoke as if these two activities—programmatic and disinterested research—competed directly against one another, but that was seldom the case. In fact, the two types coexisted and both prospered. Both were also affected by the next, thick layer in the accretion process.

Sputnik and Science, 1958–1964

The Soviet launch of Sputnik marked a new phase in the Cold War, one that emphasized domestic competition rather than military confrontation. Science, education, and space were spotlighted as the new arenas for meeting the Soviet challenge. Scientists attained representation in the nation's corridors of power and there propounded the ideology of basic research.[51] The NSF was the principal beneficiary of this new environment (aside from NIH, which continued to mushroom); but the defense establishment also played a role. Support for academic research thus grew to flood stage with increases from every tributary. NSF added $100 million to the university research economy in the initial post-Sputnik era—more than a sevenfold rise. The defense establishment, however, contributed $283 million in additional support. Moreover, although programmatic research had predominated over disinterested research in the Cold War years, the balance now clearly swung in the other direction (see Table 2).

Propensities within the different agencies varied. AEC, led during these years by Glenn Seaborg, expanded its support for university research while also defending far larger commitments to its national labs. NASA was particularly eager to accommodate academic scientists, and the early phase of its mission required the larger proportion of research to development. Currents crossed at the DOD. The creation of the Advanced Research Projects Agency (ARPA) provided an additional conduit for supporting basic research in critical fields, a role that proved

[50] Difficulties at AEC in these years included an overly restrictive policy on classification of research, no growth in the budget for biological research, and a large-scale engineering approach to fusion that was doomed without greater theoretical understanding. See Richard G. Hewlett and Jack M. Holl, *Atoms for Peace and War, 1953–1961: Eisenhower and the Atomic Energy Commission* (Berkeley: Univ. California Press, 1989), pp. 261–264. The AEC also squandered funds on developing a nuclear airplane at the Oak Ridge National Laboratory and on Lawrence's Materials Testing Accelerator at Livermore.

[51] Geiger, *Research and Relevant Knowledge* (cit. n. 1), Ch. 6; Walter A. McDougall, . . . *the Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985), pp. 141–156; and Charles S. Maier, "Science, Politics, and Defense in the Eisenhower Era," intro. to George B. Kistiakowsky, *A Scientist at the White House* (Cambridge: Harvard Univ. Press, 1976), pp. xiii–lxvii.

Table 2. Federal Support for Academic Research, 1958–1970
(in millions of dollars)

	1958	1964	1970
Total obligations to universities	254	976	1,447
Dept. of Defense	91	258	266
AEC	33	71	101
NASA	—	78	127
NSF	16	116	201
Public Health (NIH)	72	399	615
Other	41	54	137
Expenditures for research performed			
In universities	242	895	1,564
Basic research	178	768	1,296
Applied research	64	127	268
In contract centers	293	629	737

SOURCES: Obligations figures for 1958 from NSF, *Scientific Research and Development in Universities, 1958* (Washington, D.C.: GPO, 1960); for 1964 and 1970 from NSF, *Federal Support for Universities, 1986* (Washington, D.C.: GPO, 1987). Expenditures figures from NSF, *National Patterns of R&D Resources, 1989* (Washington, D.C.: GPO, 1989).

NOTE: Obligations do not equal expenditures for any given year; contract research centers are excluded from university totals for obligations and expenditures.

particularly valuable in fostering research in materials science. New systems of management and an emphasis on cost-effectiveness nevertheless kept considerable back pressure against basic research.[52] Overall, however, there can be no doubt about the nature of the new funds made available to support university research.

Early in the 1950s, in the midst of the Cold War years, universities conducted only slightly more basic than applied research. In the six years following Sputnik $590 million of support for basic research was added to the research economy, compared with just $63 million for applied. NSF and NIH accounted for most of this disparity, but the new commitments made by the defense establishment were obviously heavily weighted in the same direction. In this era of burgeoning support, academic scientists were once again in a dominant position, their services sought after by numerous, eager patrons.[53] As the funding curve reached its apogee in the late 1960s, this situation made the academy increasingly inhospitable to programmatic patrons, especially those acting in the name of national defense.

[52] Geiger, *Research and Relevant Knowledge*, Ch. 6; and Sapolsky, *Science and the Navy* (cit. n. 32), pp. 72, 86–90. The DOD's Project Hindsight, which was designed to demonstrate the irrelevance of basic research and the effectiveness of its own development efforts, illustrates this tendency: Chalmers W. Sherwin and Raymond S. Isenson, "Project Hindsight: A Defense Department Study of the Utility of Research," *Science*, 1967, *156*:1571–1577.

[53] The defense establishment had to go to considerable lengths to attract the attention of the best scientists at this time. NASA created the Goddard Institute for Space Studies for this purpose in 1961 (Newell, *Beyond the Atmosphere* [cit. n. 36], pp. 238–239); and the DOD began convening the Jason group in 1958 (Ann Finkbeiner, "Jason: Can a Cold-Warrior Find Work?" *Science*, 1991, *254*: 1284–1286).

The Crisis of Defense Research, 1965–1970

The changing tone of relations between the defense establishment and the nation's universities reflected the strong position of researchers, but it was also exacerbated by the deepening involvement in the Vietnam War. As opposition to the war rapidly evolved into a full-fledged crisis of the national polity, so too did growing hostility toward defense research transform its position on campus. Two distinct developments lay behind this change, although in conjunction they powerfully reinforced one another. The first underlying condition was brought about by the prolonged abundance of support for academic research, accompanied by the apotheosis of basic science. Together they produced a pervasive "ivory tower" mentality on university campuses. Christopher Jencks and David Riesman regarded this as part of the "academic revolution." In particular, they observed that graduate academic departments had become "for the most part autotelic[:] they resent even being asked whether they produce significant benefits to society beyond the edification of their own members."[54] Such attitudes remained latent, however, and thus difficult to document, unless provocations occurred. Angry students at Berkeley pilloried Clark Kerr for having pointed out practical, economic contributions as among the "uses of the university."[55] Outbursts of ivory-tower sentiments emerged in the sciences as well. The Stanford physics department was rent in the early 1960s as it sought to repudiate both applied physics and the linear accelerator laboratory.[56] In the late 1960s, though, the issue that brought out ivory-tower reactions was above all military research.

The political polarization that occurred on campuses as a result of the Vietnam War placed the long-standing relationship between universities and the military in a new and hostile light. Antiwar agitators grasped close-at-hand symbols to mobilize additional opposition to the war. ROTC and recruiters for the services or the CIA were early targets, but military research was soon joined to these odious manifestations of American militarism. When student activists peered into this recondite realm, they discovered that their own universities contained incongruous units—huge, secretive laboratories dedicated to weapons development or seemingly sinister institutes that advised the Pentagon war machine. (They paid little attention to individual research projects.) Why, they asked, were their universities engaged in such things? An accurate answer would have invoked the messy, illogical background of these ties stretching back to World War II, but instead the issue was addressed on normative grounds. Thus the latent ivory-tower outlook that prevailed in the 1960s was used to rationalize the iniquity of military research. The result was to create a strong presumption against university relations with the defense establishment. This attitude had consequences in three distinct arenas: the regular channels of research relationships that had been

[54] Christopher Jencks and David Riesman, *The Academic Revolution,* (Chicago: Univ. Chicago Press, 1968), p. 250.

[55] Clark Kerr, *The Uses of the University* (Cambridge, Mass.: Harvard Univ. Press, 1963); and Geiger, *Research and Relevant Knowledge,* Ch. 8. For students' use of Kerr's words against him see Seymour Martin Lipset and Sheldon S. Wolin, *The Berkeley Student Revolt: Facts and Interpretations* (New York: Anchor Books, 1965), *passim;* and the documentary film by Mark Kitchell, *Berkeley in the Sixties* (San Francisco: California Newsreel, 1990).

[56] Lowen, "Exploiting a Wonderful Opportunity" (cit. n. 26), pp. 236–273.

cultivated since the war; the peripheral units that were targets of protest; and the social science research that provoked particular public disquiet.

Even before polarization occurred, there were signs that the DOD's relations with academic research were being squeezed. In 1965 an Army spokesman reported that the "traditionally strong universities" could not handle all of the department's research needs, and that much of its support was now being directed to the second tier of institutions.[57] The implementation of THEMIS two years later confirmed this approach, as the DOD sought to develop particular specialties at neophyte research institutions which, for the most part, were less inclined to hold antimilitary views. Perhaps because of this approach, proposals to the DOD actually increased in number during these years. By this juncture political considerations had nevertheless become inescapable. The official DOD policy was to "preserve our mutually beneficial relationships with the academic research community during this period when there are potentially divisive pressures"; but even so ONR quietly dropped outspoken antiwar scientists from the rolls of grantees.[58] Regular support for university research continued despite the pressures, although it ceased to grow.[59] The greatest commotion, however, swirled around the more peripheral operations.

Antiwar protesters railed against university-affiliated centers or institutes for some time before they hit upon an effective approach. Ironically, what these units most feared was to be actually under the control of the institutions with which they were linked. When such control was threatened, they quickly chose to preserve their own academic freedom by leaving the academy.[60] Almost all such units were reconstituted as independent, nonprofit organizations and continued to function as they had before. The largest of these changes were the disestablishments of the Stanford Research Institute (1969) and of Charles S. Draper's Instrumentation Lab (1970). Prior to these moves the Institute for Defense Analysis had shed its formal university ties, and smaller units had departed from Columbia, George Washington, and American universities.[61] These changes had little effect on universities or the DOD. The decisive change in their relationship came instead from Congress.

Amid all the frayed sensibilities caused by the Vietnam War, it seems that the comparatively minor issue of Pentagon-sponsored social science research piqued congressional wrath. The military had already been embarrassed in 1965 by the collapse of Project Camelot, in which social science researchers had been used to

[57] Lt. Gen. William T. Ely, statement, in Senate Committee on Labor and Public Welfare, *Impact of Federal Research and Development Policies on Scientific and Technical Manpower,* 89th Cong., 1st sess., 1965, pp. 444–445.

[58] Brooks, "Impact of the Defense Establishment" (cit. n. 3), p. 950; and Sapolsky, *Science and the Navy* (cit. n. 32), p. 96.

[59] Not discussed here is the backlash against military research on campus that caused universities to consider measures to place various restrictions on it; see Brooks, "The Impact of the Defense Establishment," pp. 954–957. The more radical measures were never implemented: Geiger, *Research and Relevant Knowledge* (cit. n. 1), Ch. 8.

[60] Harold Orlans notes that such university policies were essentially third-party meddling in relations between sponsors and performers of research: *The Nonprofit Research Institute: Its Origin, Operation, Problems, and Prospects* (New York: McGraw Hill, 1972), pp. 147–148.

[61] Geiger, *Research and Relevant Knowledge* (cit. n. 1), Ch. 8; Dorothy Nelkin, *The University and Military Research: Moral Politics at MIT* (Ithaca, N.Y.: Cornell Univ. Press, 1972), *passim;* and Orlans, *Nonprofit Research Institute,* pp. 145–149.

bolster counterrevolutionary movements. At the end of the 1960s its interest in political structures and social systems, ostensibly because of the links to military efforts, exasperated antiwar Senators J. William Fulbright and Mike Mansfield. Under their sponsorship, a rider to the Military Authorization Act for fiscal 1970 forbade the DOD to support research unless it had "direct or apparent relationship to a specific military function or operation."[62] The Mansfield Amendment had its intended effect, not through the letter of the law, but through its spirit. The letter of the law was actually mollified the following year, and softened further in 1979, but to little effect. Within the armed services there was long-standing opposition to support for universities, and the amendment decisively tipped the balance against such activities. Reportedly, repurcussions were felt in NASA and the AEC, both of which adjusted their research programs to preclude a similar imposition. For certain, benign forms of support for academic research were expunged from DOD programs.[63]

VI. CONCLUSION

The Mansfield Amendment marked the end of one facet of a quarter-century relationship between universities and the defense establishment. For good or for ill, those agencies had bolstered university research capacities and made a varying but substantial contribution to the advancement of scientific knowledge. These were tangible accomplishments. Those who had been most critical of this partnership had generally had to invoke abstract and indirect processes—the cooptation of scientists, the steerage of research, or the cultivation of noneconomic technologies—to argue for insidious effects. Such arguments fit better the facets of this relationship that endured—the large, weapons-related laboratories, or critical fields and departments dominated by military patrons.

From 1969 to 1975 real support for basic research from the DOD fell by 50 percent. As a proportion of total federal support for academic research it dipped to just 8 percent. Support for academic research from NASA and the AEC fell in real terms as well, although for somewhat different reasons. The DOD would eventually reforge relationships with academic science, boosting its share to 18 percent in the mid 1980s.[64] In these years too the old controversies returned in new guise, as opposition to the Strategic Defense Initiative mounted on campuses. What did not revive, however, were the lost cooperative arrangements for aiding university science and scientists. Representative Don Fuqua in 1986, after supervising an extensive inquiry into federal relations with academic science, concluded that the DOD had an obligation to invest in the underlying base of university research rather than paying for only its own programmatic needs. Harvey Sapolsky, noting

[62] Military Authorization Act of Fiscal Year 1970 (Public Law 91-121, Sec. 203); see also House Committee on Science and Technology, *Science Support by the Department of Defense,* 97th Cong., 2nd sess., 1986, p. 141, pp. 56–57 (Project Camelot); and Sapolsky, *Science and the Navy* (cit. n. 32), pp. 73–77.

[63] Sapolsky, *Science and the Navy,* pp. 57–58: Sapolsky notes that the Mansfield Amendment concluded a process of accountability that started in 1950 with the DOD, and deepened with President Lyndon Johnson's call in 1966 for greater relevance in federally sponsored research.

[64] The Galt Report in 1978 recommended that the DOD substantially increase support for basic research; it marked a turning point in this respect. See House Science Committee, *Science Support by the DOD* (cit. n. 62), pp. 151–153.

the increasing turbulence in the Congress surrounding academic research, concluded his own inquiry with the observation that "science without the Navy, it turns out, is a much less independent, a much more political, undertaking."[65] The element of nostalgia evident in both of these statements is probably misplaced. When the country emerged from World War II, the defense establishment was the only institution in our society with the vested interest and the resources to support and sustain an extensive research enterprise in American universities. That it did this so liberally and so long contributed greatly to the spectacular achievements of American science. But this was a science policy appropriate to a particular historical context, a context that few would wish to see recur. Today the defense establishment fills a role that is fitting for the current historical moment—that of an interested patron of academic science within a pluralistic and mature system of university research.

[65] Don Fuqua, *American Science and Science Policy Issues,* Chairman's Report to the House Committee on Science and Technology, 97th Cong., 2nd sess., 1986; and Sapolsky, *Science and the Navy* (cit. n. 32), p. 129.