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Cold War requisitions, scientific manpower, and the production of American physicists after World War II

1. RAYMOND BIRGE'S "MAIN OBJECTIVE"

"THE MAIN OBJECTIVE of this department of physics," Raymond Birge wrote in late May 1955, "is to train Ph.D.'s in physics." Birge—iconic, somber, a displaced Yankee who traced his New England ancestry nine generations back—had been chair of Berkeley's physics department for twenty-two years; by the mid-1950s, it was the nation's largest. At the time he explained his department's "main objective," Birge was the retiring president of the American Physical Society (APS). Birge and his colleagues in Berkeley's physics department had emphasized the importance of its graduate program many times before in annual budget requests to the university administration and in funding reports to private industries; it would be easy to read such remarks as thinly-veiled requests for more funding, since training physics Ph.D.s became expensive after World War II. This time, however, Birge articulated his department's mission in a letter to a local citizen, far outside of the university bureaucracy, who had no funds to offer and who had requested no such pronouncement.[1]

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The following abbreviations are used: *AIP-EMD,* American Institute of Physics, Education and Manpower Division Records, Niels Bohr Library, American Institute of Physics, College Park, MD; *BAS*, *Bulletin of the atomic scientists; BDP*, University of California, Berkeley, Department of Physics Records, Bancroft Library, Berkeley, CA; *HDP,* Harvard University Department of Physics Records, Pusey Library, Cambridge, MA; *PDP*, Princeton University Department of Physics Records, Seeley G. Mudd Manuscript Library, Princeton, NJ; *PDP-AR*, Princeton University Department of Physics Annual Reports, Seeley G. Mudd Manuscript Library, Princeton, NJ; *PT*, *Physics today; RTB,* Raymond Thayer Birge Correspondence and Papers, Bancroft Library, Berkeley, CA.

1. Birge to William M. Roth, 31 May 1955, in *BDP*, Folder 5:143. Birge's ancestry was

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Nor was Birge's letter unique in its emphasis upon the graduate training of young physicists. In a survey of 1954, the Berkeley physicists claimed to spend only 10-15% of their time on undergraduate instruction, but 40-95% on teaching graduate students. Yet even that seemed insufficient: the new department chair, Carl Helmholz, circulated a memo to the department faculty in December 1958 reminding his colleagues that "Although research per se is important, the fundamental concern of the department is the education of students"—and, lest there be any doubt, "the graduate student class is the one which we should consider most seriously."[2] The "production" of trained physicists—Birge's "main objective," but a theme largely overlooked by historians of science—became a central, at times hysterial concern for American physicists and politicians during the decades after World War II.

"Big science" has usually been considered along two axes: funding and the scale of experimental apparatus.[3] Both the source and the scale of funding for scientific research changed dramatically with World War II. By 1953, the level of spending for "fundamental" physics research within the United States was 20 to 25 times greater than it had been in 1938, even after adjusting for inflation, and the

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noted in Yvonne Young (Birge's secretary) to Larkin Kerwin (President of the Canadian Association of Physicists), 24 May 1955, in *RTB*. A. Carl Helmholz, who became department chair in 1956, pleaded with Berkeley's chancellor in a 1956 budget request that "we have an obligation and an increasing need to train more Ph.D.'s in physics and this does require research money." Helmholz to Clark Kerr, 28 Mar 1956, in *BDP*, Folder 1:20. See also Helmholz to Kerr, 5 Mar 1958, in *BDP*, Folder 1:28, and Helmholz to Glenn Seaborg, 6 Mar 1959, in *BDP*, Folder 1:29.

2. See Birge's summary on "Form 2A (Academic year): Percentage distribution of time of faculty members among services performed for academic year, 1953-1954," completed as part of the "Restudy of the needs of California in higher education, 1954." Birge's report, dated 2 June 1954, is in *BDP*, Folder 1:15, along with data for individual faculty members; A.C. Helmholz, mimeographed agenda, 8 Dec 1958, in *BDP*, Folder 2:2.

3. Derek de Solla Price, *Little science, big science* (New York, 1963); Alvin Weinberg, *Reflections on big science* (Cambridge, 1967); Daniel J. Kevles, *The physicists: The history of a scientific community in modern America*, 3rd edn. (Cambridge, 1995 [1978]), chapts. 21-23; Robert Seidel, "A home for big science: The Atomic Energy Commission's laboratory system," *HSPS, 16:1* (1985), 135-175; Paul Forman, "Behind quantum electronics: National security as basis for physical research in the United States, 1940-1960," *HSPS, 18:1* (1987), 149-229; Everett Mendelsohn, M. Roe Smith, and Peter Weingart, eds., *Science, technology, and the military* (Boston, 1988); Peter Galison and Bruce Hevly, eds., *Big science: The growth of large-scale research* (Stanford, 1992); James Capshew and Karen Rader, "Big science: Price to the present," *Osiris, 7* (1992), 3-25; Stuart Leslie, *The Cold War and American science: The military-industrial-academic complex at MIT and Stanford* (New York, 1993); Andrew Pickering, "Cyborg history and the World War II regime," *Perspectives on Science, 3* (Spring 1995), 1-48; and Peter Galison, *Image and logic: A material culture of microphysics* (Chicago, 1997), esp. chapts. 4, 5, and 9. Many patterns for what became postwar big science had precedents during the interwar period at Berkeley's Radiation Laboratory; J.L. Heilbron and Robert Seidel, *Lawrence and his laboratory: A history of the Lawrence Berkeley Laboratory*, Vol. 1 (Berkeley, 1989).

vast majority of this spending came from defense-related agencies within the federal government.[4] This outpouring of defense dollars paid for instruments and equipment on an unprecedented scale.

Yet there was a third axis of "bigness" that rarely appears in these accounts: big enrollments of graduate students in the sciences. The number of new physics doctorates granted each year within the United States ballooned immediately after the war, growing at a faster rate than any other field. The growth in graduate-student enrollments took on an explicitly political formulation. Some physicists and government bureaucrats advanced a Cold War logic according to which the training of exponentially-increasing numbers of professional physicists was used to justify all the other "big" expenditures commonly associated with "big science." For others, graduate-student training assumed equal importance with the other "bigs." For more than two decades after World War II, most physicists, government officials, and nationally-syndicated journalists equated the nation's security with the production of young physicists. Most American physicists did not spend the bulk of their time working on weapons during the 1950s. Yet they received money from defense-related bureaus to create an "elite reserve labor force" of *potential* weapons-makers in the ranks.[5]

The Cold War logic of wartime requisitions and physicist-manpower points to a less overt, yet longer-lasting form of politicization for the nation's physicists than those usually considered by historians. More was at stake than the visible signs of American physicists' political engagement after World War II, either as elite government consultants or as special victims of McCarthyism.[6] The demands for physicist-manpower were tied directly to the contours of the Cold War, rising immediately after the war, receiving a strong jolt with the United States' entry into the Korean War and again after the surprise launch of Sputnik, and crashing only with détente, Vietnam-era protests against defense-related research on campuses, and massive cuts in defense spending.

Questions of pedagogy and scientific "manpower" provide a framework within which to re-examine the vexed question of whether the sudden sea-change in source and scale of funding matter to the content of postwar physics. Did military-derived "big science" leave a lasting epistemic impression? The question can be addressed from the everyday exigencies of training students and pursuing research. The manpower question also allows consideration of the effects of the Cold War mobilization on theoretical physics, and not only on the experimental physics with which most previous literature on "big science" is concerned. The new demands for training ever-rising numbers of students helped to solidify American physicists' style of work after the war. Physicists' attitudes and judgments about what counted as ap-

4. Forman (ref. 3), 190.

5. Cf. Chandra Mukerji, *A fragile power: Scientists and the state* (Princeton, 1989), chapt. 1. Mukerji focuses on oceanographers in the 1980s. For physics in Cold War Europe, cf. John Krige, "The Ford Foundation, European physics, and the Cold War," *HSPS, 29:2* (1999), 333-361, and "NATO and the strengthening of Western science in the post-Sputnik era," *Minerva, 38* (2000), 81-108.

propriate topics for research and teaching make most sense when set within the context of the postwar escalation in manpower.

2. THE POPULATION EXPLOSION

Yale University became the first domestic institution to grant a Ph.D. in physics, when it bestowed one on Arthur Williams Wright in 1861 for his study of orbital mechanics. One thousand physics Ph.D.s followed between 1861 and 1929, while just over fourteen hundred were produced during the decade 1930-1940 alone, despite Depression conditions (figure 1).[7]

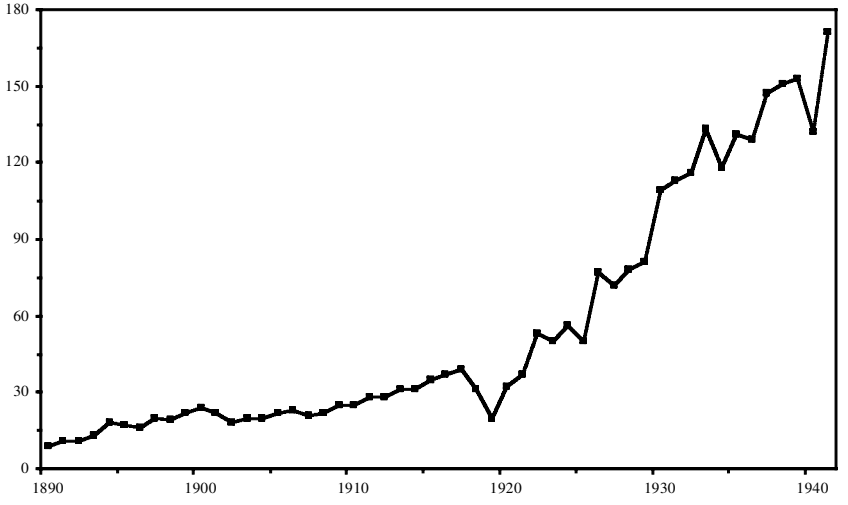

FIG. 1 Total number of Ph.D.s in physics granted each calendar year by U.S. institutions, 1890-1941. *Source:* Based on data in Adkins (ref. 7), 278-281.

Based on similar growth in research funding, pages published in the professional journals, and membership in the professional societies during the 1930s, Spencer Weart has suggested that the postwar expansion of American physics had its roots not initially in World War II but rather in the prewar decade. Surveying the period

6. Kevles (ref. 3), chapts. 22-23; Ellen Schrecker, *No ivory tower: McCarthyism and the universities* (New York, 1986), 149-160, 272-275; Jessica Wang, *American science in an age of anxiety: Scientists, anticommunism, and the Cold War* (Chapel Hill, 1999); Silvan Schweber, *In the shadow of the bomb: Oppenheimer, Bethe, and the moral responsibility of the scientist* (Princeton, 2000); David Kaiser, "Nuclear democracy: Political engagement, pedagogical reform, and particle physics in postwar America," *Isis, 93* (June 2002), 229-268.
7. M. Lois Marckworth, *Dissertations in physics: An indexed bibliography of all doctoral theses accepted by American universities, 1861-1959* (Stanford, 1961), ix-xi. Figure 1 is based on data from Douglas Adkins, *The great American degree machine: An economic analysis of the human resource output of higher education* (Berkeley, 1975), 278-81. Adkins'

1920-70, Weart concludes, provides an overall "impression of continuity." The war, on this telling, cemented pre-existing exponential growth trends for the "physics business" in the United States.[8]

Growth during the 1930s, however, proved to be but a shadow of the growth to come. As figure 2 reveals, the postwar boom in physics Ph.D.'s made a dramatic break with the past in both absolute numbers and rates of change.[9]

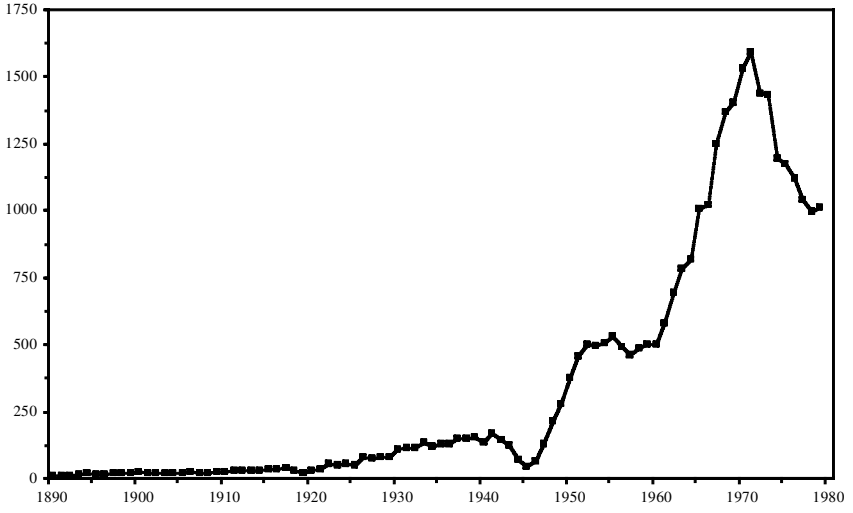

FIG. 2 Total number of Ph.D.s in physics granted each calendar year by U.S. institutions, 1890-1979. *Source:* Based on data in Adkins (ref. 7), 278-281, and National Research Council (ref. 9), 79.

Averaged over the period 1890-1941, the annual number of Ph.D.s granted in physics by U.S. institutions doubled steadily every thirteen years; the corresponding number for 1945-71, is seven years, nearly twice as fast (Appendix tables A.1 and A.2). Though the overall number of new physics Ph.D.s continued to grow throughout the Depression, the rate slowed considerably: at the rate of increase during 1930-39, it would have taken eighteen years to double the annual output of physics doctorates. The immediate postwar years, on the other hand, saw lightning growth: between 1945-51, the number of physics Ph.D.s awarded annually by U.S. institutions doubled every 1.7 years—a rate increase of over tenfold. During the mid-1950s, with the number of new physics Ph.D.s per year fluctuating around 500, it

numbers agree to within 10% of Marckworth's as well as with the data in Spencer Weart, "The physics business in America, 1919-1940: A statistical reconnaissance," in Nathan Reingold, ed., *The sciences in American context: New perspectives* (Washington, D.C., 1979), 295-358.

8. Weart (ibid.), 330.

9. Adkins (ref. 7), 278-81 for 1890-1971, and in National Research Council, *Postdoctoral appointments and disappointments* (Washington, D.C., 1981), 79, for 1972-79. The data for 1960-71 in these two sources always agree to better than 8% and usually to within 2%.

took only two years to produce as many as the United States had produced during the seventy years separating the Civil War and the Great Depression. Following the Soviets' surprise launch of Sputnik in the fall of 1957, the number of Ph.D.s in physics awarded by U.S. institutions took off steeply once again, doubling every 6.2 years during the period 1958-68 (tables A.3 and A.4).

During the 1950s and 1960s, the tremendous and rapid growth in American physics departments resulted in lack of office space, overcrowded laboratory conditions, proliferation of new bureaucratic procedures, a widespread feelings of "facelessness," and a perilous loss of "intimacy." Routine social events, such as the annual picnics of Berkeley's physics department, became logistically exhausting affairs.[10] The frequent complaints about overcrowding, from both students and faculty, may explain the flattening of the physics Ph.D.-curve during the 1950s despite strong demand. Enrollments had swollen to over three times their prewar highs, far faster than the departments' faculties and physical plant. Despite a boom in new physics buildings and building extensions, department chairs across the country complained bitterly about their lack of adequate space.[11] The next dramatic rise in the annual output of physics Ph.D.s, after Sputnik, was accomplished primarily by increasing the number of doctoral institutions, rather than by squeezing more students into the existing graduate programs: the number of institutions granting Ph.D.s in physics within the United States doubled between 1959 and 1967.[12] The number of physics Ph.D.s granted each year jumped by a factor of three, to over 1,500 by the late 1960s.

These trends may be compared usefully with the more general expansion in American higher education over the course of the 20th century. Between 1890 and 1941, the rate of increase in physics Ph.D.s awarded each year was 87% of the growth-rate averaged across all fields; between 1945 and 1951, on the other hand, the factor was 200%. No other field came close: physics grew nearly twice as quickly as chemistry, for example, and fully 12% faster than its nearest competitors, engineering and psychology. During the 1950s, most fields, like physics, settled into a steady state. Exponential growth resumed across the boards following Sputnik. Although the margin had shrunk compared with the immediate postwar period, physics once again outpaced all fields in its rate of growth except for engineering and mathematics.[13]

Demand for new physics Ph.D.s far outstripped the ever-increasing supply. The Placement Service of the American Institute of Physics (AIP) reported in 1952

10. David Kaiser, "The postwar suburbanization of American physics," in Kaiser, *Making theory: Producing physics and physicists in postwar America* (Ph.D. dissertation, Harvard University, 2000), 57-112.
11. Ibid.
12. Kevles (ref. 3), 388.
13. The "baby boom" powered the general expansion: the class that entered college in 1964 was the largest ever, up 37% from the previous year alone. Todd Gitlin, *The sixties: Years of hope, days of rage*, rev. edn. [New York, 1993 (1987)], 11-21, 164. Berkeley's physics department chair cited enrollment projections as early as 1959 as a reason to begin increas-

that "for three years running the number of positions to be filled has been several times the number of available registrants."[14] A decade later, only 449 physicists registered with the Placement Service at a meeting of the American Physical Society, at which various employers had hoped to fill 514 jobs.[15] A senior researcher noted in 1970 that through most of the 1950s and 1960s, "most, if not all, doctoral or master's candidates [in physics and engineering] could obtain as many job offers as he or she was willing to take interviews."[16] Who wanted these physicists? For what were they being trained?

3. FROM "MARKETS" TO "MANPOWER"

"A going concern must find a market for its product," Daniel Elliott explained to his colleagues in the pages of the *American physics teacher* in 1938, "and this is true of the profession of physics." As another physics teacher put it in the mid-1930s, "We folks in the teaching business have a product to sell."[17] Philip Morse described the vigorous "sales effort" that people like Karl Compton and Robert Millikan, then presidents of MIT and Caltech respectively, had to mount during the 1930s to help place the newly-minted physics Ph.D.s in industrial jobs, since university positions had become scarce in proportion to the number of graduate students.[18] American physicists in the Great Depression discussed the fruits of their pedagogical efforts—the growing numbers of men and the small trickle of women who earned advanced degrees in physics—in terms of "sales," "markets," and, above all, "products."

The commodity terminology shifted following the nation's economic recovery and experience in World War II. When invoked after the war, "commodity" connoted rationing and conservation of a precious resource. "In a time of national emergency," opined AIP director Henry Barton in December 1948, "this country would think nothing of spending a million dollars to survey, develop, and conserve a short commodity like natural rubber or tin. Highly trained and able human re-

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ing the department's faculty and overall budget in anticipation of the baby boom: Helmholz to Glenn Seaborg, 6 Mar 1959, in *BDP*, Folder 1:29.

14. Henry Barton, "AIP 1952 annual report," *PT, 6* (May 1953), 4-9, on 6.

15. "Placement register statistical comparison, APS-AAPT Annual Joint Meeting, 1963 to 1969," n.d., ca. 1970, in *AIP-EMD*, Box 13, Folder, "Placement literature."

16. Russell G. Meyerand, Jr.'s remarks at the conference on "The supply, need, and utilization of graduate scientists and engineers" (May 1970) are quoted in Sanborn Brown and Brian Schwartz, eds., *Scientific manpower: A dilemma for graduate education* (Cambridge, 1971), 47-48. Meyerand was the Director of Research at United Aircraft Research Laboratories.

17. Daniel Elliott, "Some economic aspects of physics," *American physics teacher, 6* (1938), 198; Wheeler Davey, "Report of Conference on Applied Physics," *Review of scientific instruments, 7* (1936), 119, both as quoted in Weart (ref. 7), 318-319, 352n111.

18. Philip Morse, *In at the beginnings: A physicist's life* (Cambridge, 1977), 134; H.A. Barton, interview with Charles Weiner, 3 and 16 Mar 1970, 17-8, 38-39, 44, 54 (Niels Bohr Library, American Institute of Physics, College Park, MD).

sources, viewed as a commodity, are far more important." Two years later, AEC Commissioner and former Princeton physics department chair Henry DeWolf Smyth explained in a speech before the American Association for the Advancement of Science that "scientific manpower" was a "war commodity," a "tool of war," and a "major war asset," and hence needed to be "stockpiled" and "rationed." MIT's Dean of the Sciences, George Harrison, testified before the Preparedness Subcommittee of the Senate Committee on the Armed Forces in January 1951 to the need for the "production, conservation, and expenditure" of the nation's physicists.[19]

Just as they had before the war, "product" and "production" therefore continued to dominate American physicists' discussions of their students—as in the conference on "The Production of Physicists," sponsored jointly in 1955 by the National Research Council (NRC) and the AIP.[20] In the postwar period, however, the concern for "sales" and "market" was replaced by a new obsession with "manpower." The federal government's Office of Defense Mobilization issued policy statements during the Korean conflict on "Training and utilization of scientific and engineering manpower," and the Office for Naval Research maintained a "Manpower Branch" of its Human Resources Division to record how many students emerged from the nation's universities with higher degrees in the sciences. The AIP established its own Education and Manpower Division to coordinate its efforts with the government's. The National Science Foundation (NSF) at the same time began issuing annual "American Science Manpower" reports.[21] The economic metaphor gave way to a military one in consequence of the new employment realities: rather than requiring a strenuous sales effort to create jobs for their students, physicists after World War II struggled to graduate advanced degree-holders in physics quickly enough to meet Cold War demands.

Fellowships, training, and the draft before the Korean War

The first postwar graduate students often cited their wartime service as an inducement for pursuing a Ph.D. in physics. "My interest in physics," wrote a graduate student in Harvard's physics department in September 1948, "was aroused

19. Henry Barton, "Institute doings," *PT, 1* (Dec 1948): 15; Henry DeWolf Smyth, "The stockpiling and rationing of scientific manpower," *PT, 4* (Feb 1951), 18-24, on 19; George Harrison, "Testimony on manpower," *PT, 4* (Mar 1951), 6-7, on 6.
20. The conference was held in West Virginia from 31 Mar - 2 Apr 1955 and reported in the June issue of *Physics today*. An unsigned report, "NRC-AIP Conference on the Production of Physicists," *PT, 8* (June 1955), 6-12, was followed by subcommittees' reports and some of the papers presented.
21. M. Trytten, "The organization of scientific manpower: Reports of government advisory groups," *BAS, 6* (1950), 355, 375-378; the special issue devoted to "scientific manpower" in *Scientific American, 185* (Mar 1951); National Manpower Council, *A policy for scientific and professional manpower* (New York, 1953); Barton, "AIP 1952 Annual Report," 5-6. Weart cites data from the ONR "Manpower branch" in Weart (ref. 7), 335n2. On the NSF reports, see Brown and Schwartz (ref. 16), 23n1.

while I was working on the Atomic Bomb in New Mexico while in the Army." Interest piqued, the "promise of money to come from the G.I. Bill" helped to seal this student's decision to pursue a Ph.D. The student's reminiscences were drawn out by an anonymous questionnaire that greeted the 83 Harvard physics graduate students who had completed at least one year of graduate study as they queued up for registration in 1948. Over one-quarter of those who returned the questionnaire mentioned wartime service experiences as an inducement to study physics. One peer put it simply: "The war introduced me to the scientific life." Another mentioned a "feeling that the work [in physics] was important as a result of the war." Two-thirds of the returning physics graduate students had served in the military during World War II. Several mentioned the aid provided by the G.I. Bill among the many factors which had prompted them to pursue a Ph.D. in physics.[22]

The Cold War was an even better recruiter. Just six weeks after the end of World War II, for example, the Scientific Panel of the Interim Committee on Atomic Power recommended to General Leslie Groves that the Army continue to support university physics research as a training ground for personnel to serve in various applied-physics projects—a plan Groves quickly approved.[23] Nor would these training efforts be restricted to university campuses. In March 1946, enterprising East Coast physicists convinced Groves that the best way "to prevent disintegration of [the Army's] nuclear research organization" was to establish new laboratories at which students could receive "advance[d] training in nuclear studies"—a pitch that helped to found the Brookhaven Laboratory on Long Island.[24]

The Office of Naval Research (ONR) was explicit about its rationale for becoming, in the late 1940s, the single largest patron of "big science" physics projects in the nation's universities. As Emanuel Piore, director of the ONR's Physical Sciences Division, explained, the "[m]otivation within the Navy" was to make up for the "deficit in technical people" left in the wake of World War II, "which cost the country one to two graduate-school generations of scientists." The ONR aimed to "stimulate" universities' "normal function of research and graduate instruction," and evaluated funding proposals according to "the training possibilities the project will afford to young men."[25] Piore had phrased things differently to an advisory

22. "Opinions of returning graduate students in physics," 86-page mimeographed report, 1948, 73-82. Harvard University Archives, Pusey Library, Cambridge, Massachusetts, UAV 691.448. Approximately two million veterans took advantage of the G.I. Bill. Roger Geiger, *Research and relevant knowledge: American research universities since World War II* (New York, 1993), 40-41.

23. Robert Seidel, "Accelerating science: The postwar transformation of the Lawrence Radiation Laboratory," *HSPS, 13:2* (1983), 375-400, on 382-383.

24. Richard Hewlett and Oscar Anderson, Jr., *The new world: A history of the Atomic Energy Commission*, Vol. 1, *1939-1946* (University Park, 1962), 633-634; Allan Needell, "Nuclear reactors and the founding of Brookhaven National Laboratory," *HSPS, 14:1* (1983), 92-122; Seidel (ref. 3); Robert Crease, *Making physics: A biography of Brookhaven National Laboratory, 1946-1972* (Chicago, 1999), chapts. 1-4.

25. Emanuel Piore, "Investment in basic research," *PT, 1* (Nov 1948), 6-9, on 6-7; Richard Hewlett and Francis Duncan, *A history of the United States Atomic Energy Commission*,

group to the Pentagon: "Graduate students working part time are slave labor." The Navy's best economic interests would be served by placing more and more of its work with them.[26] To the ONR, graduate training justified lavish spending.

The Atomic Energy Commission, founded by Congress in 1946, eventually took over most of these Army and Navy installations, creating a coast-to-coast national laboratory system and supporting dozens of university-based laboratories. Internal AEC memos from early 1947 reported that the Commission's rationale for funding all of these laboratories was, in John Heilbron's paraphrase, "to train personnel for employment in the laboratories of federal agencies or their contractors—it being supposed that university accelerator laboratories would attract the best talent and train it in ways useful to government." The AEC's General Advisory Committee (GAC) similarly advocated continued funding of nuclear research at universities so as to provide training for young physicists.[27] So important was the creation and maintenance of this standing army of physicists that the AEC agreed in 1948 to fund not one but two accelerators in the billion-volt range, at Berkeley and at Brookhaven, even though the GAC advised that only one such machine would be needed scientifically. The AEC decided to build both machines lest "morale" at the losing laboratory suffer. As Smyth explained in his role as AEC Commissioner in 1949, the duplication would bring the government not just "big equipment," but "big groups of scientists who will take orders."[28] Manpower production entailed all the other trappings of postwar big science.

In 1948, the AEC put together a program of graduate-student fellowships under the watchful eyes of the Congressional Joint Committee on Atomic Energy. As the Committee's chair, Senator Bourke Hickenlooper (R., Iowa), remarked to the AEC's chair David Lilienthal in July 1948,[29]

> It is an assumption on the part of the Joint Committee that the purpose of this fellowship program is to establish a nucleus of highly trained individuals who

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Vol. 2, *Atomic shield, 1947-1952* (University Park, 1969), 80; 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 Mendelsohn (ref. 3), 3-45; Harvey Sapolsky, *Science and the Navy: The history of the Office of Naval Research* (Princeton, 1990).

26. Piore's remark to the Pentagon's Research and Development Board is quoted in Rebecca Lowen, *Creating the Cold War university: The transformation of Stanford* (Berkeley, 1997), 106.

27. J.L. Heilbron, "An historian's interest in particle physics," in Laurie Brown, Max Dresden, and Lillian Hoddeson, eds., *Pions to quarks: Particle physics in the 1950s* (New York, 1989), 47-54, on 51; Seidel (ref. 23), 393. See also Robert Seidel, "The postwar political economy of high-energy physics," in Brown et al, ibid., 497-507; Daniel Kevles, "Cold war and hot physics: Science, security, and the American state, 1945-56," *HSPS, 20:2* (1990), 239-264, and "K1S2: Korea, science, and the state," in Galison and Hevly (ref. 3), 312-333; Schweber, "Big science in context: Cornell and MIT," in ibid., 149-183.

28. Hewlett and Duncan (ref. 25), 249-250; Seidel (ref. 23), 394-397; Smyth as quoted in Seidel (ref. 3), 148. See also Seidel (ref. 10).

29. Hickenlooper to Lilienthal, 30 Jul 1948, reprinted in *Hearings before the Joint Commit-*

> will increase the general knowledge in scientific fields and at the same time provide a pool from which some individuals will be drawn to active employment on the atomic energy program.

Lilienthal agreed with this interpretation, though he emphasized in later testimony before the Joint Committee that "no commitments as to employment are made at the time of the fellowship award."[30] After the Joint Committee learned that an AEC fellowship had been given to a self-proclaimed Communist student, however, it tightened the rules. Applicants to the program in 1950 had to propose topics of research "sufficiently related to the atomic energy field to justify presuming that the candidate may be considered a potential employee of the AEC or one of its contractors;" soon further revisions required that AEC postdoc applicants spend their fellowships working on classified research.[31] That brought what was wanted: three-quarters of the students who completed their physics Ph.D.s in 1953 with AEC funding took jobs with the AEC upon graduation.[32] Besides federally funded fellowships from the AEC, ONR, and NSF, physics graduate students during the 1950s competed for fellowships from industrial defense-contractors like Westinghouse, General Electric, DuPont, Raytheon, and IBM, which amounted to indirect underwriting of physicists' education by the defense department.[33]

Funding physics students was one task; keeping them out of the armed services was another. In the midst of debates during the late 1940s between a pro-

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tee on Atomic Energy, Congress of the United States, Eighty-First Congress, First Session, on Atomic Energy Commission Fellowship Program, May 16, 17, 18, and 23, 1949 (Washington, D.C., 1949), 5.

30. Ibid., 4.

31. "Footnotes to security: AEC fellowships," *PT, 3* (Apr 1950), 28-29; Hans Bethe and C.J. Lapp (NRC Fellowship Office), correspondence during March and April 1950, in Folder 11:9, Hans A. Bethe Papers, Division of Rare and Special Collections, Cornell University Library, Ithaca, New York. On the controversy over the AEC fellowships see also ref. 29; E.R. [Eugene Rabinowitch], "The 'cleansing' of AEC fellowships," *BAS, 5* (June-Jul 1949); 161-162; "The Fellowship Program: Testimony before the Joint Committee," *BAS, 5* (June-Jul 1949), 166-178; "Loyalty tests cause cut in AEC Fellowship Program," *BAS, 6* (Jan 1950), 32; "The curtailment of the AEC Fellowship Program," *BAS, 6* (Jan 1950), 34, 62-63; "Loyalty tests for science students?," *BAS, 6* (Apr 1950), 98; and Wang (ref. 6), chapt. 7.

32. Heilbron (ref. 27), 51, citing an AEC news release dated 30 Apr 1953.

33. Birge to Robert Gordon Sproul (President of the University of California), 15 Apr 1949 and 15 Apr 1951, in *RTB*; Birge to Joseph Barker (President of the Research Corporation), 28 Aug 1950, in *RTB*; Birge to Clark Kerr (Chancellor of the Berkeley campus), 23 May 1955, in *BDP*, Folder 1:35; J.C. Street to Julian Hill (Executive Secretary of DuPont), 29 Jan 1960, in *HDP*, "Correspondence: 1958-60," Box A-P, Folder "1959-60 Grants-in-aid," and William Preston to Glenn Giddings (Educational Relations consultant of General Electric), 15 Feb 1960, in the same folder. See also the annual reports from the chair of Harvard's physics department to the university president, in *HDP*, "Correspondence: 1953-57 and some earlier," Box 1, and "Correspondence: 1958-60," Box A-P; and Lowen (ref. 26), chapts. 5-6.

posed "universal military training" and the "selective service" model of World War II, President Truman had agreed that students studying "essential" topics, namely science, engineering, or medicine, should be deferred from active service because of their value to the nation. Local draft boards did not always have or act on definitions of "necessary and irreplaceable" scientific specialties.[34] *Physics today* ran a notice in its issue of December 1948 alerting "[a]ll employers of young scientists" to "prepare themselves *immediately* to handle draft cases. Men who clearly should be classified II-A are being inducted through failure of their employers to learn the regulations and take the necessary steps in time." The notice admonished, "Write letters. Don't wait for forms." The AIP's director Henry Barton resounded the alarm in the next issue: "The time has come for those responsible for the training or employment of physicists to take seriously their responsibilities under the Selective Service Act." Department chairs and their colleagues should be pro-active with the local draft boards, Barton pressed, and should move immediately to retain deferrals for their physics students—even if the students themselves wanted to be drafted![35]

Despite such alarmist pronouncements, however, by the late 1940s it appeared to some commentators that the shortages of trained physicists created by World War II had been eliminated. MIT physicist and president Karl Compton confidently wrote to President Truman in November 1949 that military research and development was no longer hampered by shortages in trained personnel.[36] A few months later, the AEC's advisor on scientific personnel, Philip Powers, agreed with Compton's assessment: that "[f]ar more scientists have been coming off the production line in the last few years than was anticipated." The nation's research and development capabilities had doubled between 1947 and the beginning of 1950, Powers said, whereas the President's plan called for doubling by 1957. The problem had become the balance of supply and demand.[37]

Fighting in Korea: A new phase in manpower requisitions

The outbreak of the Korean War upset the balance. "Manpower" in physics once again became a matter of national security.[38] Within a year after the U.S. entered the Korean War in June 1950, the federal government increased its demand for physicists by a factor of ten; by February 1952, the number of industrial

34. Joel Spring, *The sorting machine revisited: National educational policy since 1945* (New York, 1989), 40-53; James Hershberg, *James B. Conant: Harvard to Hiroshima and the making of the nuclear age* (Stanford, 1993), 310-312, 516-520, 538-552.
35. "Notice!," *PT, 1* (Dec 1948), 34; Henry Barton, "Institute doings," *PT, 2* (Jan 1949), 14.
36. Karl Compton to President Truman, 2 Nov 1949, quoted in Kevles (ref. 27), 247.
37. Philip Powers, "The changing manpower picture," *The scientific monthly, 70* (Mar 1950), 170, and "Balance needed: Manpower picture changing for science," *PT, 3* (June 1950), 28.
38. Kevles (ref. 27); Hershberg (ref. 34), chapts. 27-28; Lowen (ref. 26), 120-121; and Wang (ref. 6), chapt. 8.

openings for physicists was also ten times higher than it had been during the winter of 1950.[39] The Korean War threw the nation's physics departments into what Princeton's department chair aptly termed "a semi-wartime economy of science."[40]

Just weeks into the conflict, the chair of the NRC's Division of Mathematics and Physical Sciences circulated a memorandum among trusted colleagues. A policy statement drawn up together with the director of the AIP, the memo sought to establish "procedures for utilizing our manpower in physics in helping to solve our military and other related problems."[41] Unlike the situation in 1939, the Department of Defense and the AEC had already established "very greatly expanded laboratories," manned by "expanded staffs of physicists." Whereas the nation had to scramble in the early 1940s to build up Los Alamos, Oak Ridge, and the MIT Radiation Laboratory, the postwar laboratories were already "ready to function in far less time than would be required to establish large centralized project laboratories." With these labs already up and running, the physicist-policymakers hoped there would be no need to yank physicists and their students into centralized facilities, no need to repeat the pattern of "manpower utilization" of the war years. They continued:

> Unless a very short emergency (not more than three years) is contemplated, it is of great importance to continue the training of promising students to full competence in physics. If this is not done, we cannot staff the expansion of physics work already contemplated and we cannot build for the future scientific strength of the nation. We must not have again an almost total interruption of the supply of new physicists such as occurred from 1941 to 1945, from which we have now barely recovered. We have now no "stockpile" of physicists….If any emergency lasting ten years or more is contemplated—and we have been informed that such is the case—it is important to continue fundamental as well as applied research, even in the interests of military security. Such security ten years from now will be affected by our success now in excelling our enemies in the basic research out of which new kinds of weapons will be developed.

The single most important resource the nation could protect was graduate education in physics.[42]

39. National Manpower Council (ref. 21), 195.
40. Donald Hamilton, acting chair of the Princeton Physics Department, Annual Report for 1950-51, 13, in *PDP-AR* (14 Sep 1951).
41. R.C. Gibbs (NRC) to A.G. Shenstone (chair of the Physics Department at Princeton), 7 Aug 1950, and response 18 Sep 1950, in *PDP*, Box 1, "Chairman's records," Folder "Scientific manpower."
42. R.C. Gibbs and H.A. Barton, "Proposed policy recommendation," 1 Aug 1950, in *PDP*, Box 1, "Chairman's records," Folder "Scientific manpower." The visiting committee to Harvard's physics department in 1952 commended its faculty for its valiant contributions to "defense mobilization," though no faculty member had to "abandon...his instruction of graduate students; and no professor is so bedeviled by commitments to the mobilization program that his work is seriously injured." The visiting committee's report, dated 14 Apr 1952, is in

Members of the physics department at the University of Rochester, New York, took direct action to safeguard the manpower resource. Citing "the existing national emergency," they opened four new teaching assistantships and five new research assistantships. Several of Berkeley's physics faculty sent their graduate students to work as postdocs at the newly-formed weapons laboratory at Livermore.[43] Princeton's John Wheeler told his department chair that the hydrogen bomb would be good for Princeton's graduate students: "Insofar as graduate students are going to have to get part of their training working on university sponsored war projects"—an assertion seemingly so obvious that Wheeler felt no need to justify it—"it will be hard for them to do better than on the thermonuclear project for all-around range of ideas." In a classified report of 1954, Hans Bethe explained that "the great effort [previously] made" at the nation's universities "to train these young people [in physics] has since borne fruit. Only because of that effort were laboratories like Los Alamos able to gather their large staffs of highly competent scientists in the years since 1948"—and only with such large staffs could work on the hydrogen bomb move forward.[44]

In this emergency, physicists scrutinized the draft policies that threatened to remove physics graduate students from their studies. AIP director Barton offered a proposal in November 1950 to the director of the manpower office of the National Security Resources Board, which had been given the task of reviewing the Selective Service arrangements in the light of the Korean conflict. Barton proposed the formation of a "Scientific and Technological Service" in which promising undergraduate and graduate students in the sciences would be classified for service. Draft-age young men who qualified as bona fide science students "would appear at once in a pool subject to disposition in the national interest." The pool, "would constitute a national resource of great importance, a resource in all too short supply, a resource which must be conserved, reserved for essential uses only, and augmented and refined through all possible means." A National Board of Scien-

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HDP, "Correspondence: 1958-60," Box Q-Z, Folder "1958-59 Visiting Committee." Princeton's department chair reported in 1951 that five senior professors from his department were absent for war work during 1950-51, one (Henry Smyth) as chair of the AEC, others (such as John Wheeler and Eugene Wigner) in AEC laboratories at Los Alamos and Savannah River. Hamilton, Annual Report 1950/1, in *PDP-AR*.

43. "Supplementary memorandum for prospective graduate students," mimeographed notice circulated by the University of Rochester physics department, winter 1951, in *PDP*, Box 2, Folder "Scientific manpower." On the founding of Livermore, see Seidel (ref. 3), 151-153, and Herbert York, *The advisors: Oppenheimer, Teller, and the superbomb*, 2nd edn. (Stanford, 1989), 121-135. Lists of Berkeley physics students who planned to work at Livermore may be found in the "Students advanced to candidacy," filed regularly between October 1951 and March 1954, in *BDP*, Folders 7:8 - 7:12.

44. Wheeler to Shenstone, 8 Jan 1951, as quoted in Peter Galison and Barton Bernstein, "'In any light': Scientists and the decision to build the hydrogen bomb," *HSPS, 19:2* (1989), 267-347, on 320; Hans Bethe's report, "Observations on the development of the H-Bomb," was declassified in 1980 and reprinted in York (ref. 43), 163-181; quotation on 166.

tific and Technological Personnel should be established with responsibility to maintain an "adequate flow of scientists-in-training through professional (graduate) schools and other procedures to augment and improve the quality of the scientific and technological force of the United States against the possibility of an all-out emergency, and the rehabilitation needs after such an emergency."[45]

MIT's George Harrison lobbied for the formation of a similar special category of selective service in his testimony before the Preparedness Subcommittee of the Senate Committee on the Armed Forces in January 1951. Harrison explained to the senators that new weapons "require inventive imagination and rapid development [and] result mainly from the cooperative effort of young men, most of whom are only a short time out of college." "Every young scientist can serve as a soldier and carry a gun," Harrison argued, "but not every young soldier can help develop a new weapon like the proximity fuze that will replace the services of many thousands of soldiers." Given that "[p]hysicists are now in dangerously short supply," Harrison, like Barton, urged that a National Scientific Personnel Board be established, to induct young physicist-draftees to make, rather than use, new weapons. Similar proposals for a "Scientific Service Corps" and a "Reserve Specialists Training Corps" came from the AEC's Smyth and from the Scientific Manpower Advisory Committee of the National Security Resources Board. The Advisory Committee's proposal, modeled on the Reserve Officer Training Corps (ROTC), suggested that students in the "Reserve Specialists Training Corps" spend four months in the standard military basic training before returning to their classrooms, where they would wear uniforms or badges while continuing their training.[46]

Although the physicists' proposals for a new form of selective service were not implemented—indeed, some physicists complained bitterly after the Korean War about the "completely irrational" drafting of physics graduate students near the end of the war—government bureaucrats did not miss the underlying logic behind their proposals.[47] The Federal Security Agency's Office of Education and the Bureau of Labor Statistics made explicit the link between graduate training in physics and the nation's defense: "If the research in physics which is vital to the nation's survival is to continue and grow," they asserted, "national policy must be concerned not only with keeping the young men already in the field at work but also with insuring a continuing supply of new graduates."[48] Likewise, the director of the AEC's Physics and Mathematics Branch proposed in July 1951 that the AEC build more accelerators so as to keep physicists' morale high and their students sharp. He went through a simple calculation: if *N* nuclear physicists were "willing,

45. Henry Barton, "Emergency use of manpower: A proposal," *PT, 4* (Jan 1951), 26-27.
46. Harrison (ref. 19), 6-7; Smyth (ref. 19), 23; "Scientific manpower: NSRB Advisory Group calls for action," *PT, 4* (Mar 1951), 28-9. See also "Physicists and military mobilization: Draft deferment of physics students," *PT, 3* (Sep 1950), 23-24; "Science and mobilization," *PT, 4* (Nov 1951), 4-5; and Spring (ref. 34), 44-49.
47. "Scientific manpower at midyear," *PT, 7* (Oct 1954), 4-5, on 4.
48. Quoted in Barton (ref. 14), 6.

able, and eager to use particle accelerators, and on average five such men per accelerator is an effective team," then the AEC should build ($N/5$) accelerators, or two per year for as long as "the international situation remains roughly as at present."[49]

There was a self-serving note in the physicists' policy proposals. Not only were they calling for the continued smooth, non-centralized operation of large-scale physics, together with special deferment policies for their students, but they also ignored the interdisciplinary character of weapons work.[50] Yet few people challenged their proclamations. What is remarkable about the physicist-policymakers' response to the Korean conflict was the uniformity with which *other* people, not directly involved with academic physics, adopted and amplified their early call for vastly increased manpower production in the name of national defense. From the Bureau of Labor Statistics to the AEC, the equation between physics manpower and national security went unquestioned.[51]

After Korea: No demobilization

The cries about physics manpower shortages continued well after fighting ended in Korea in July 1953. Complaints, predictions, and warnings about a devastating shortage of Ph.D. physicists continued unabated well into the 1960s. During the mid-1950s, neither an AIP annual report nor an APS Presidential Address could go by without a mention of the manpower shortages in physics.[52] The conference on "The production of physicists" sponsored by the NRC and AIP in 1955 began "with the premise that there is now a shortage of physicists that is not likely to be

49. Joseph Platt to Paul McDaniel, "Extent of Off-Site Research Program in Physics," 27 Jul 1951, as quoted in Seidel (ref. 10), 502.
50. Lillian Hoddeson et al., *Critical assembly: A technical history of Los Alamos during the Oppenheimer years, 1943-1945* (New York, 1993); Pickering (ref. 3); Galison, *Image* (ref. 3), chapts. 4, 9.
51. Rebecca Press Schwartz argues in an unpublished paper that the physicists' version of the division of labor in weapons work was built into the Smyth Report on the Manhattan Project: for security reasons, Smyth had to emphasize the contributions of physicists, much of whose work had already been published in the open literature, rather than the closely-guarded inputs from materials science and engineering. Henry DeWolf Smyth, *A general account of the development of methods of using atomic energy for military purposes under the auspices of the United States government, 1940-1945* (Washington, D.C., 1945). For decades after his report was published, Smyth received angry letters from chemists and engineers who complained that he had slighted their contributions. My thanks to Schwartz for sharing a copy of her paper.
52. See, e.g., Barton (ref. 14), 5-6; M. Stanley Livingston, "Employment problems of young physicists," *PT, 8* (Apr 1955), 20-21; Raymond Birge, "Physics and physicists of the past fifty years," *PT, 9* (May 1956), 20-28, on 23-24; "Scientific manpower," *PT, 8* (June 1955), 22-24; John Phelps and Ernest Pollard, "Physics, physicists, and security," *PT, 9* (Dec 1956), 23-26; "Manpower and education," *PT, 10* (Jan 1957), 50.

relieved for a decade or longer."[53] "The present shortage of physicists and the anticipated worsening of this situation in the future," exhorted one of the committee chairs from the conference, "must be the concern of all career physicists who acknowledge a responsibility to their profession and to the well-being of the nation."[54]

One of the conference participants asked why so few American boys and girls grew up to become physicists. Why was it, Dael Wolfle asked, that "of 10,000 boys and girls who are bright enough to become physicists," who "possess the intellectual interest, habits, and abilities required of a physicist," only fifty completed undergraduate majors in the subject, and only fifteen pursued graduate study? The next speaker reminded his fellow conferees that "the 'time of decision' for a potential science student is often the 8th grade when electives are selected for the following year."[55] Physicists in the mid-1950s pondered how best to reach this larger, untapped pool of elementary school and junior high school students to begin to close the manpower shortage.[56] And this when the nation's universities were graduating *three times* as many Ph.D.s a year than the prewar records. Nonetheless, leaders of the American physics community aimed at a faster reproduction. "In spite of the present importance of physics," the outgoing president of the APS declared in an address in February 1956, "we constitute an extremely small fraction of the total [U.S.] population."[57]

Efforts to protect and increase the nation's supply of physicists bordered on the absurd. In June 1955, *Physics today* carried notice that a New York City company had offered to arrange for "newly developed medical examinations" to be given to those "difficult to replace" scientists who might otherwise have missed work because of food allergies. Although, by the company's own estimate, food allergies affected more than 90% of the nation's population, the proposed medical attention would be doled out preferentially in the interest of "conserving our present pool of scientific manpower."[58]

53. "NRC-AIP Conference on the Production of Physicists," *PT*, *8* (June 1955), 6-12, on 7.
54. R.S. Shankland, "Recommendations, NRC-AIP Conference on the Production of Physicists, Physics Committee," *PT, 8* (June 1955), 13-14, on 13.
55. "NRC-AIP Conference" (ref. 53), 8-9. Birge quoted similar statistics; "of the original primary school population," only 0.4 percent completed bachelor's degrees in physics, with correspondingly lower numbers for advanced degrees. Birge (ref. 52), 24; Marsh White, "Estimation of numbers of physicists in training during the next decade," *American journal of physics, 22* (1954), 421-422, upon which Birge relied.
56. John Rudolph argues that many of the efforts to reform high-school and college physics curricula during the 1950s and 1960s aimed less at closing the manpower shortage than at increasing basic science literacy and a cultural appreciation for physics. Rudolph, *Scientists in the classroom: The Cold War reconstruction of American science education* (New York, 2002), esp. chapts. 3-5.
57. Birge (ref. 52), 23.
58. "Extending longevity of scientists," as reported in "Scientific manpower," *PT, 8* (June 1955), 23-24.

On September 5, 1957, exactly one month before the launch of Sputnik revved the rhetoric of manpower still higher, Senator Henry Jackson (D., Washington) released a report entitled "Trained manpower for freedom." Citing both the new opportunities as well as the new challenges of the atomic age, Jackson announced that "the member states of NATO now face an authentic crisis, in the form of across-the-board shortages of trained manpower," where, he was quick to add, the relevant "trained manpower" included only "scientific and technical personnel." It was a new age, Jackson declared, in which the "the decisive factor is highly trained managerial and technical brain power."[59] One month before the United States would lose the first round of the "space race," and a few years before presidential candidates would debate the extent of the "missile gap," Jackson capitalized on the competition in scientific education and manpower. "The Soviets are now graduating trained technical people at a per capita rate roughly twice that of the NATO community as a whole," Jackson declared, without specifying his source. "The quality of Soviet instruction is high." With the Soviets marching forward on the scientific manpower front, the U.S. had to make the most of the "greatest resource of the state and of the free world community," that is, scientific talent. "Nothing is more precious." He outlined various "talent development programs" including fellowships for high-school and college students, special summer study institutes, and awards for students and teachers who excelled in science education. These resources, Jackson explained with a telling metaphor, "should be used as catalytic agents which, so to speak, can initiate educational chain reactions extending over the broadest possible scientific and technological front."[60]

Immediately after Sputnik's launch, President Eisenhower announced that the nation needed to create scientists even more urgently than it needed to pursue "all other immediate tasks of producing missiles [and] of developing new techniques in the armed services." His scientific advisors emphasized even more emphatically than before that missiles would come only with investment in education.[61] Mere

59. Henry M. Jackson, "Trained manpower for freedom," 16-page report addressed to the Special NATO Parliamentary Committee on Scientific and Technical Personnel; quotations from pp. 3-4, copy in *PDP*, Box 1, "Chairman's records," Folder, "Scientific manpower." Jackson's advisory committee for preparing the report included several physicists and mathematicians (Richard Courant, Maria Goeppert Mayer, Edward Teller, and John Wheeler), the president of MIT (James Killian), the former president of the National Academy of Sciences (Detlev Bronk), and the president of the Motion Pictures Association (Eric Johnston). For background to Jackson's report, see Krige, "NATO" (ref. 5), 88-93.
60. Jackson (ref. 59), 4, 6-10. Summer study institutes for bringing high school physics teachers up to date had been in place for several years; John Rudolph, "From World War to Woods Hole: The use of wartime research models for curriculum reform," *Teachers College record* (in press, 2001). See also, Frederick Seitz, "Factors concerning education for science and engineering," *PT, 11* (Jul 1958), 12-15; United States Department of Health, Education, and Welfare, *Education in the USSR* (Washington, D.C., 1957); and "Education in the Soviet Union: Emphasis on science," *PT, 11* (Jul 1958), 12-16.
61. Eisenhower, as quoted in "An emerging science policy," *PT, 10* (Dec 1957), 32.

days after the launch of Sputnik, the AIP tried to ascertain whether appropriate "educational chain reactions" could be induced to meet the latest challenge. Its Education and Manpower Division distributed questionnaires to every department within the United States that offered a four-year undergraduate major in physics. Within three months, 490 of the 536 departments had responded—a 91% response rate that in itself indicates how seriously the nation's physics departments considered the situation. More than ninety percent of the respondents reported some "shortage" in its physics teaching staff. Handling the rising influx of undergraduate and graduate majors in physics overloaded the staffs of nearly half of the responding departments. Almost an equal number reported that the inflated teaching loads had materially reduced the time available for research. Although the administrations at these institutions had authorized a total of 403 new appointments of Ph.D. physicists to alleviate the teaching pressures, only 254 of these authorized positions were expected to be filled during the 1957/8 academic year; a large proportion of the responding department chairs predicted even worse difficulties in procuring adequate teaching staff for the following year.[62] By the time the AIP completed this study, the circulation of the monthly newsletter from a private lobbying group called the "Scientific Manpower Commission," which reported vital statistics on fluctuating supply and demand for trained scientific and technical personnel, had risen above 12,000.[63]

4. OVERPRODUCTION

Initiatives similar to Jackson's proposals were put in place soon after Sputnik, thanks especially to the National Defense Education Act of 1958; some had been operating for several years.[64] Fantastic increases in the numbers of physics Ph.D.s awarded annually—a jump from 500 in 1955, to 1,000 in 1965, to 1,500 by 1970—resulted. Still there were not enough. Analysts projected cataclysmic shortages. "Manpower crisis found in physics. Report says 20,000 jobs will go unfilled by 1970" announced a *New York Times* headline on July 6, 1964. The newspaper took its facts from the AIP's Education and Manpower Division. "By 1970, the experts predict," the *Times* echoed the AIP's report, "industry and government will have a

62. W.C. Kelly, "Report on a study of the supply of physics teachers in U.S. colleges and universities offering a major in physics," 7-page report dated 1 May 1958, but in circulation since mid-April. The surveys were distributed on 31 Oct 1957. In *AIP-EMD*, Box 5, Folder, "AIP-publications, Kelly, W.C."
63. "Scientific Manpower Commission, 1958," 2-page pamphlet in *AIP-EMD*, Box 4, folder "Scientific Manpower Commission, Washington, D.C."
64. "An emerging science policy" (ref. 61); C.J. Overbeck, "The physicist and the National Defense Education Act of 1958," *PT, 12* (May 1959), 22-24; Rudolph (ref. 56); Robert Divine, *The Sputnik challenge: Eisenhower's response to the Soviet satellite* (New York, 1993); Barbara Barksdale Clowse, *Brainpower for the Cold War: The Sputnik crisis and National Defense Education Act of 1958* (Westport, CT, 1981).

deficit of at least 20,000 physicists—about one-third of the total number required." There had been 29,000 physics-related jobs and only 17,300 physicists to fill them in 1960; the "low output of key scientific and educational manpower is expected to result in critical shortages in 1970." Within days word of the impending "crisis" had spread from London's *Financial Times* to the *Washington Post*, and from the *Wall Street Journal* to *Business Week*.[65]

Under increasingly melodramatic headlines, the same story also appeared across the country. The *New York Herald Tribune* trumpeted "Physicists: We need lots more;" the *Philadelphia Daily News,* "Peril looms in shortage of physicists;" the Wilmington, Delaware *Evening Journal*, "Physics keystone of power/most Americans unaware of meaning;" and the Orange, California *News*, "Plight of the nation: 'Vanishing physicists.'" The *Akron Beacon Journal* saw the bright side: "Looking for job future? Just study physics." In all, at least forty-nine different newspapers and magazines in twenty-nine different states ran a story based on the AIP's report.[66]

Many papers peppered their coverage with editorials about the indispensability of physicists to the nation and the world. The UPI story, which many local papers printed while changing only the headline, used language only slightly less sensationalistic than Senator Jackson's. "Physics is the science which splits the atom, produced the H-bomb and the bright, peaceful promises of atomic energy, and is the indispensable keystone of many technologies. It is the science of matter and motion, and these are the fields in which nations contend for superiority." An article which ran in both the Moline, Illinois *Dispatch* and the Beloit, Wisconsin *News* began similarly:

> It can be persuasively argued that our age is the age of physics. Other branches of science have made tremendous strides since the turn of the century, but it is physicists who have transformed man's understanding of the universe. Nor is this new understanding purely abstract. Physics has a practical role in government and industry. The entire space program, for example, rests upon physics discoveries….What it all adds up to is that, in an age of great emphasis on physics, we are not training enough physicists to meet the demand.

The *Rochester Times-Union* in Rochester, New York put it more simply: physicists are "a prime national resource in the nuclear and space age."[67]

65. Clippings in *AIP-EMD*, Box 6, Folder, "News media coverage, 1964 manpower study." *Physics today*'s article based on the AIP report contained none of the histrionics of the newspaper accounts: "The supply [of physics Ph.D.s] seems to be increasing faster than the demand. Some alleviation of the shortage of physicists can be foreseen, but the shortage will probably persist through 1970." Fred Boercker, "Education and manpower in physics," *PT, 17* (Sep 1964), 42-50, on 50. Boercker, the Director of Manpower Studies at AIP, had written the report he abstracted.
66. Clippings (ref. 65).
67. Ibid.

The predictions of shortfall could not have been further from the mark. The escalation of Ph.D. production did not run after a lack, but produced a glut. The droves of new physics Ph.D.s slid into the worst job shortage the nation has ever seen—far more protracted than any employment-placement difficulties during the Depression years. Within just one year of the widely-quoted AIP report of 1964, well over twice as many young physicists registered with the AIP placement service than there were jobs available. By 1968, nearly 1,000 applicants crowded the halls of one of the APS annual meetings, scrambling for interviews for one of the 253 advertised jobs; the following year, almost 1,300 young physicists competed for 234 jobs. At the annual April meetings of the APS, held in Washington, D.C., the numbers turned grimmer: 1,010 physicists competed for 63 jobs in 1970, 1,053 for 53 in 1971. Only sixteen employers bothered to show up for the APS meeting in April 1971, down by more than one hundred from the number who had flocked to the meeting in 1962. The AIP's Placement Service Advisory Committee estimated in October 1970 that by July of 1971, the nation's "demand level" for scientists and engineers would slip to 44 percent what it had been a decade earlier.[68] American physics had indeed reached a crisis by 1970, exactly when the 1964 report had predicted.

The employment crisis, which lasted for the better part of the 1970s, had its roots in the same ground as the previous boom: the Cold War. Protests against classified research on university campuses, heightened by Vietnam-era protests against the defense establishment more generally, rattled the Cold War logic that equated physics manpower with national defense. The Mansfield Amendment of 1969, which placed restrictions on the Defense Department's funding of basic research, curtailed opportunity.[69] More immediate in their effects, however, were rapid, deep cuts in defense spending. "The federal government is the largest single employer of scientists and engineers in the U.S.," explained an internal memorandum from the AIP's Education and Manpower Division in October 1970. The federal government had increased its employment of scientists and engineers by 49 percent between 1959 and 1969; new government jobs for physicists rose at a rate of nearly ten percent a year between 1960 and 1968. At the end of that rise, one fifth of the nation's physics Ph.D.s worked directly for the government. In 1969, the Defense Department employed 12,000 physical scientists, other federal agencies another 19,000.[70] And, of course, the majority of university-employed physics Ph.D.s had part or all of their research budgets from the federal government.

68. "Placement register, statistical comparison, APS-AAPT Annual Joint Meeting, 1963 to 1969" (not dated, ca. 1970), and "Summary: Placement service register, The American Physical Society Meeting, Washington, D.C.," dated 3 June 1971, both in *AIP-EMD*, Box 13, Folder "Placement literature;" "Supply and demand," Oct 1970, in *AIP-EMD*, Box 13, Folder "Placement Service Advisory Committee."
69. Kevles (ref. 3), 24-25; Leslie (ref. 3), chapt. 9; Robert Serber with Robert Crease, *Peace and war: Reminiscences of a life on the frontiers of science* (New York, 1998), chapt. 9.
70. "Supply and demand" (ref. 68); Robert Alberty's report in Brown and Schwartz (ref. 16), 23-33.

Détente meant bad economic news for the nation's physicists. Deep cuts in spending for defense and space knocked the government's science-employment system far out of equilibrium. In 1968, ten percent of all jobs in the nation—all jobs, not just jobs in science or engineering—stemmed from the defense industry. Between 1968 and 1971, one quarter of these jobs disappeared. Sixteen-thousand scientists and engineers, each holding advanced graduate degrees, lost their aerospace-industry jobs during 1970, joining the half-million employees in the nation's defense plants laid off by October 1970; another half-million were expected to meet the same fate within the next year. The defense-spending cuts, combined with the wane of baby-boom enrollments, cut into the academic job market for physicists as for everyone else. At least 45 and as many as 58 university departments had interviewed candidates for jobs at each of the April APS meetings between 1962 and 1968. The number of academic jobs on offer at the meeting dropped to 21 in 1969 and to 12 in 1971—a factor of four decrease in as many years.[71] Soon the numbers of physics Ph.D.s awarded each year began to fall (see figure 2).

Four years into the physics-job depression, the APS and the American Association of Physics Teachers convened a special meeting under the title, "Tradition and Change in Physics Graduate Education." Over 150 representatives from government, industry, and the nation's universities—three times more than the anticipated attendance—met at Penn State during the summer of 1974. They focused their attention on one central question: did the "traditional training in physics"—a tradition forged over a quarter-century of Cold War expansion—serve the "best interests of society, of the physics community, and of the individual physicist?"[72] What it meant to do physics, and what it meant to be trained as a physicist, required serious re-examination in the mid-1970s, just as it had after World War II.

About half of the students in Berkeley's department during the early and mid-1950s expressly wanted to lend their hand to the Cold-War cause and half did not want to have any part in the new form of "civil service." For every student who replied "Not interested in war work" on the department's semi-annual survey of job preferences, another wrote down "Academic or war research," or "prefer work connected with national defence," or "'Essential' industry or Gov't." The 50-50 split remained steady between 1951 and 1954, during as well as after the Korean War.[73] The obvious Cold War reasoning for training scientific manpower framed students' choices—for or against a particular course—just as plainly as it did for

71. "Summary" and "Supply and demand" (ref. 68). An entry to the enormous literature generated by the job crunch that began in 1970 can be made through the records within *AIP-EMD*, Box 13; Brown and Schwartz (ref.16); Weart (ref. 7), 327-331; Lee Grodzins, "Supply and demand for Ph.D. physicists, 1975 to 1986," in Martin Perl, ed., *Physics careers, employment and education* (New York, 1978), 52-86.
72. APS, *Physics and society: The newsletter of the forum on physics and society, 6* (Jan 1977); "Tradition and change in physics graduate education," *PT, 27* (Nov 1974), 91; and D. Allan Bromley, "Physics in perspective," *PT, 25* (Jul 1972), 23-35.
73. "Students advanced to candidacy," Oct 1951 through Mar 1954, in *BDP*, Folders 7:8-7:12.

Senator Jackson or department chair Birge. At a time when the textbook for a graduate-level nuclear physics might be the AEC's handbook, *The effects of atomic weapons*, and job postings within Berkeley's department as well as *Physics today* routinely included positions in "nucleonics" as well as guided missiles, students did not have much trouble detecting the Cold War logic of physicist manpower.[74]

5. COLD WAR PHYSICS?

Did the historically bounded Cold-War context influence the research that American academic physicists undertook after the war? Paul Forman has famously asserted that they suffered from "false consciousness," trading in their intellectual autonomy for defense dollars. Physicists "pretended a fundamental character to their work that it scarcely had;" it had merely "instrumental significance…to their military patrons." In response to these charges of intellectual "seduction" by the military, Daniel Kevles has argued that certain areas of scientific research "can take on lives of their own as intellectually compelling areas of inquiry," even if their initial impetus comes from designs with military relevance. There is no trans-historical significance, Kevles argues, to terms such as "basic" or "fundamental" physics: "Physics is what physicists do."[75]

There is another way to frame the question. American physicists were not as concerned with policing a *cordon sanitaire* between "basic" and "applied" physics as they were with coping with the sudden population explosion of physics students whom the Cold War had produced. The student overflows, and the concrete requirements for teaching rooms full of pupils rather than mentoring a handful of individual disciples, helped to solidify certain research traditions and approaches. The tremendous, unprecedented demographic shift helped to drive a *pedagogical* emphasis upon *efficient*, *repeatable*—and thereby *trainable*—techniques of calculation, thus solidifying a prewar instrumentalist trend. Such a pedagogical program, centered increasingly around Feynman diagrams and similar calculational techniques, could be taught in fine Taylorist, factory-production style. They were amenable to teaching and evaluation in ways that other aspects or styles of practicing physics were not.[76] As one former physics graduate student from Harvard later

74. Lists of textbooks, 1952-54, in *BDP*, Folders 8:19-8:20; collections of incoming announcements for employment possibilities, 1945-55, in *BDP*, Folder 4:27; Hughes Research and Development Laboratories, "Guided missiles," full-page advertisement in *PT, 9* (Nov 1956); 14.
75. Forman (ref. 3), 224-9; Kevles (ref. 27), 262-264.
76. Rudolph (ref. 60) similarly notes the postwar emphasis on techniques, rather than conceptual development, in Cold War curricular reforms. Andrew Warwick and Ursula Klein have drawn attention to the roles of "theoretical technology" and "paper tools" in physical scientists' work: Warwick, "Cambridge mathematics and Cavendish physics: Cunningham, Campbell, and Einstein's relativity, 1905-1911. Part I: The uses of theory," *Studies in history and philosophy of science, 23* (1992), 625-656; Klein, "Techniques of modelling and paper-tools in classical chemistry," in Mary Morgan and Margaret Morrison, eds., *Models as mediators: Perspectives on natural and social sciences* (New York, 1999), 146-167.

recalled, "I went to graduate school [in the late 1950s] to learn about foundations. I was taught, instead, how to do physics. In place of wisdom, I was offered skills."[77] Epistemological musings or the striving for ultimate theoretical foundations—never a strong interest among American physicists even before the war—fell beyond the pale for the postwar generation and their advisors.[78]

Physicists sometimes made the pedagogical bases of their research choices explicit. Freeman Dyson, Richard Feynman's young collaborator who did more than anyone else to bring Feynman's new diagrammatic techniques to young physicists' attention, framed his efforts in pedagogical terms. Writing to a skeptical Robert Oppenheimer in October 1948, Dyson argued that Feynman diagrams were "considerably easier to use, understand, and teach" than any of the rival formalisms. His testimonial to the intertwined intellectual and educational merits of the diagrams was echoed by practically every textbook author on particle physics, quantum field theory, dispersion relations, and the *S*-matrix program over the next two decades.[79]

Concern with the pedagogical effectiveness of physicists' research topics likewise appears in Birge's recommendation for early promotion of one of Berkeley's experimentalists. Emphasizing that "one of the greatest tasks now confronting the department is the direction of the research work of our graduate students," Birge explained that "more than any other member of the staff, [this professor] has been 'imposed upon' in this connection. He now has *eighteen* graduate students formally enrolled for research under his direction." More important, he had proven to be an effective leader of their research, as evidenced by their impressive publication record. "I have asked [him] to compile a list of the publications of his students, because such publications should be considered effectively as part of his research record." Success in advising graduate students made the faculty member too precious to risk losing to another university.[80]

77. Evelyn Fox Keller, "The anomaly of a woman in physics," in Sara Ruddick and Pamela Daniels, eds., *Working it out* (New York, 1977), 78-91, on 83.
78. Silvan S. Schweber, "The empiricist temper regnant: Theoretical physics in the United States, 1920-1950," *HSPS, 17:1* (1986), 55-98, and *QED and the men who made it: Dyson, Feynman, Schwinger, and Tomonaga* (Princeton, 1994); Nancy Cartwright, "Philosophical problems of quantum theory: The response of American physicists," in Lorenz Krüger, et al., eds., *The probabilistic revolution* (2 vols., Cambridge, 1987), *2*, 417-35; Alexi Assmus, "The Americanization of molecular physics," *HSPS, 23:1* (1992), 1-34; Andrew Pickering, "From field theory to phenomenology: The history of dispersion relations," in Brown, et al. (ref. 27), 579-599.
79. Freeman Dyson, unpublished memorandum to J. Robert Oppenheimer, 17 Oct 1948, quoted in Schweber, *QED* (ref. 78), 522-523; Kaiser, *Making theory* (ref. 10), 378-391, and "Stick-figure realism: Conventions, reification, and the persistence of Feynman diagrams, 1948-64," *Representations, 70* (2000), 49-86. Cf. David Kaiser, "A $_\psi$ is just a $_\psi$? Pedagogy, practice, and the reconstitution of general relativity, 1942-1975," *Studies in history and philosophy of modern physics, 29* (1998), 321-338.
80. Birge to Dean A.R. Davis, 9 Apr 1951, in *RTB*.

For a young theoretical physicist on Berkeley's faculty, however, advising graduate students cut the other way. After only a year and a half at Berkeley, he was advised to look for a position elsewhere. The professor's problem stemmed from the crush of students who required advising.[81] The young theorist's classroom teaching was not at issue, nor his diligence; "I have on more than one occasion found him working in his office on Saturday afternoon, or on Sunday, when very few other persons were in the building," Birge wrote on his behalf.

Despite his merits, the man could not attract graduate students: "In general [he] is interested in field theories of a rather abstract nature. It is somewhat the sort of thing that Einstein has worked on for many years (without any important results)." That was a mistake.[82]

> It is felt here that when one has attained an established position, he can afford to work on a highly important, but very difficult problem, if necessary for years without visible results....But a young man must choose subjects that show promise of publishable results in a relatively short time. It is particularly important to select subjects of this character for graduate student research—subjects that are not trivial, but at the same time are not unduly difficult or too time-consuming.

Writing in favor of the dismissed theorist to Harvard's Kenneth Bainbridge, Birge explained,[83]

> [He] is interested in field theory and the work he is now doing may turn out to be important. It is difficult to judge the matter at this time. But it is not the sort of work that can readily be used for Ph.D. theses, nor the kind that leads to rapid or voluminous publication. Hence it seemed to our committee that [he] was not carrying his fair share of the load of graduate student research, and was not likely to in the immediate future. It therefore seems desirable to replace him by someone who will be more useful to us.

Assessing the episode two years later, Birge made the equation between research topic and pedagogical needs crystal clear:[84]

> He turned out to be a very good teacher and the main criticism of his research was that it was in a rather abstract field. In particular, the subjects that he was suggest-

81. Leonard Loeb to Birge, 14 Oct 1952, in *RTB*, Box 19, Folder, "Loeb." The theorist had been hired to help fill the gap left by the firing or resignation of the physics department's theorists (and two experimentalists) over the loyalty oath (Kaiser (ref. 6)). Thus the teaching crunch in Berkeley's department had as specific tie to Cold War politics.
82. Birge to E. B. Roessler (University of California, Davis), 29 Nov 1952, in *RTB*.
83. Birge to Bainbridge, 11 Feb 1953, in *RTB*. Birge sent identical letters to Professors Halliday (University of Pittsburgh), Duncan (Pennsylvania State College), Macdonald (Boston University), Ellickson (University of Oregon), Howard (University of Oklahoma), and Bengston (University of Nebraska), during the first three weeks of March 1953.
84. Birge to Alfred Kelleher, 3 Nov 1954, in *RTB*. Birge's designation of the unfortunate

> ing to graduate students for their research seemed too difficult and too abstract for that sort of thing. It was therefore felt that he would not be particularly valuable to us since we have a very large number of graduate students who must be guided to the Ph.D. degree.

Having the nation's largest graduate program, Berkeley could not afford certain types of research. Like the promoted experimentalist, the theorist could boast effective classroom teaching and dutiful work habits. But there was no room for theory too difficult for graduate students' theses. The Berkeley cases probably represent a wider trend: most physics departments in the United States reported having too many graduate students for their faculty to handle. During the manpower build-up phase of the Cold War, physicists had to choose their research so as to support throngs of graduate students on their coattails. Pedagogical realities constrained research possibilities.[85]

In reference to the argument between Forman and Kevles, it was not military spending *per se*, but the pedagogical requirements of training graduate students that shaped the character of postwar physics research in theoretical as well as experimental physics. The pedagogical requirements entailed by the sudden exponential growth in graduate student numbers during the Cold War reinforced a particular instrumentalist approach to physics. Feynman diagrams and similar "paper tools" flourished within this context, while other aspects of theoretical work appeared irrelevant or unsupportable. By keeping the exigencies of graduate training in focus, we can begin to unpack the effects of the Cold War on American physics.

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theorist's research as overly "abstract" was exaggerated; he worked on phenomenological applications of quantum field theories and methods to improve approximate calculations—hardly an "Einsteinian" quest for a unified field theory. Kaiser, *Making theory* (ref. 10), 185.

85. Lowen (ref. 26), chapts. 4-5, points out that Frederick Terman, first as dean of Stanford's engineering school and later as the university's provost, encouraged faculty to select research topics most likely to attract military contracts, on which they could hire and train graduate students.

Appendix
Ph.D. Production Rates in the United States, 1890-1971

This appendix contains information on the growth in the numbers of Ph.D.s awarded each year in various fields by U.S. institutions from 1890 to 1971.[85] The fields included each accounted for at least 1 percent of the total number of doctorates granted in any year. The numbers of Ph.D.s awarded each year in physics, like the total number of Ph.D.s in all fields, rose exponentially during this period apart from World Wars I and II. However, the doubling period d_i varied across fields and over time. The tables give d_i (the doubling period for each subject as measured in years), the ratio $d_{physics}/d_i$, and the multiple-correlation coefficient for each entry, R^2, which indicates how well the data fit the pure exponential curve; a perfect fit would have $R^2 = 1.000$. Note that the smaller the doubling period, the more rapid the growth.

Table A.1
Doubling-period for the number of Ph.D.s granted annually by U.S. institutions, 1890-1941

	d_i	R^2	(d_{phys}/d_i)
All Fields	11.64	0.939	1.13
Physics	13.18	0.928	1.00
Engineering	7.68	0.935	1.72
Math	10.97	0.928	1.20
Chemistry	12.46	0.940	1.06
Biology	10.26	0.958	1.29
Earth Science	15.07	0.878	0.87
Economics	14.42	0.889	0.91
Political Sci	14.08	0.893	0.94
Sociology	11.22	0.923	1.18
Psychology	13.43	0.925	0.98
History	11.77	0.948	1.12
English	11.01	0.948	1.20
Foreign Lang.	9.85	0.956	1.32
Religion	16.50	0.894	0.79

86. Based on data in Adkins (ref. 7), 252-429.

Table A.2
Doubling-period for the number of Ph.D.s granted annually by U.S. institutions, 1945-71

	d_i	R^2	(d_{phys}/d_i)
All Fields	7.79	0.916	0.90
Physics	7.00	0.811	1.00
Engineering	5.37	0.928	1.30
Math	6.48	0.934	1.08
Chemistry	12.16	0.819	0.58
Biology	8.06	0.942	0.87
Earth Science	9.90	0.925	0.71
Economics	8.35	0.924	0.84
Political Sci	8.25	0.859	0.85
Sociology	8.56	0.865	0.82
Psychology	7.00	0.812	1.00
History	9.90	0.854	0.71
English	7.97	0.926	0.88
Foreign Lang.	9.37	0.869	0.75
Religion	15.40	0.662	0.45

Table A.3
Doubling-period for the number of Ph.D.s granted annually by U.S. institutions, 1945-51

	d_i	R^2	(d_{phys}/d_i)
All Fields	2.95	0.944	0.59
Physics	1.74	0.964	1.00
Engineering	1.97	0.950	0.88
Math	2.72	0.880	0.64
Chemistry	3.13	0.954	0.56
Biology	3.90	0.920	0.45
Earth Science	2.92	0.926	0.59
Economics	3.02	0.959	0.58
Political Sci	2.42	0.907	0.72
Sociology	3.04	0.952	0.57
Psychology	1.97	0.985	0.88
History	3.06	0.967	0.57
English	3.52	0.931	0.49
Foreign Lang.	4.57	0.804	0.38
Religion	3.04	0.739	0.57

Table A.4
Doubling-period for the number of Ph.D.s granted annually by U.S. institutions, 1958-68

	d_i	R^2	(d_{phys}/d_i)
All Fields	7.00	0.983	0.89
Physics	6.24	0.977	1.00
Engineering	4.31	0.991	1.45
Math	4.85	0.989	1.29
Chemistry	10.66	0.975	0.59
Biology	7.30	0.950	0.86
Earth Science	9.12	0.931	0.68
Economics	7.07	0.973	0.88
Political Sci	7.37	0.945	0.85
Sociology	8.35	0.911	0.75
Psychology	8.56	0.957	0.73
History	7.62	0.928	0.82
English	6.73	0.985	0.93
Foreign Lang.	6.06	0.903	1.03
Religion	22.36	0.592	0.28

DAVID KAISER

Cold War requisitions, scientific manpower, and the production of American physicists after World War II

ABSTRACT:
Beginning most explicitly with the American involvement in the Korean War, and continuing unabated until 1970, the demand for Ph.D.-trained physicists in the United States followed a particular Cold War logic of "manpower" and requisitions. This logic, rehearsed by senior physicists, university administrators, government commissions, individual senators, and newspaper reporters from across the country argued that young graduate students in physics constituted the nation's most precious resource. The purported need to train ever-larger numbers of physics graduate students was often used to justify the structural rearrangements associated with "big science," from huge federally-subsidized budgets to factory-sized equipment. The exigencies of training roomfuls of graduate students, rather than mentoring handfuls of disciples, reinforced the prevailing American pragmatic, instrumentalist approach to theory.