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The Parasites: Synchrotron Radiation at SLAC, 1972–1992

ABSTRACT

The synchrotron radiation activities at SLAC National Accelerator Laboratory (formerly Stanford Linear Accelerator Center) started out in 1972 as a small-scale Stanford University project. The project gradually grew to become one of the first national centers for synchrotron radiation in the United States and, eventually, an independent laboratory in charge of its own accelerator machine and organizationally a part of SLAC. This article tells the story of the first two decades of these activities, when the synchrotron radiation activities operated parasitically on the SLAC site, entirely peripheral to SLAC's main scientific mission in high energy physics. The article's meticulously detailed account of the history of the parasitic period of

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The following abbreviations are used: AEC, United States Atomic Energy Commission; ALS, Advanced Light Source; ANL, Argonne National Laboratory; APS, Advanced Photon Source; BNL, Brookhaven National Laboratory; CEA, Cambridge Electron Accelerator; DESY, Deutsches Elektronen-Synchrotron (German Electron Synchrotron); DOD, United States Department of Defense; DOE, United States Department of Energy; ERDA, United States Energy Research and Development Administration; EXAFS, Extended X-ray Absorption Fine Structure; FEL, free electron laser; Fermilab, Fermi National Accelerator Laboratory; GeV, giga electron volts; HEP, high-energy physics; HEPL, High Energy Physics Laboratory (at Stanford University); LBL, Lawrence Berkeley National Laboratory; LCLS, Linac Coherent Light Source; LEP, Large Electron-Positron Project; linac, linear accelerator; MIT, Massachusetts Institute of Technology; MoU, memorandum of understanding; NASA, National Aeronautics and Space Administration; NLC, Next Linear Collider; NSF, U.S. National Science Foundation; NSLS, National Synchrotron Light Source; PEP, Positron-Electron Project; *PiP*, *Physics in Perspective*; SLAC, Stanford Linear Accelerator Center; SLAC Archives, Menlo Park, CA; SLC, SLAC Linear Collider; SPB, Science Policy Board; SPEAR, Stanford Positron-Electron Accelerator Ring; *SPP*, *Science and Public Policy*; SRC, Synchrotron Radiation Center; SSC, Superconducting Super Collider; SSRL, Stanford Synchrotron Radiation Laboratory; SSRP, Stanford Synchrotron Radiation Project; XPS, X-ray Photoemission Spectroscopy.

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synchrotron radiation at SLAC constitutes an important and interesting piece of modern science history, complementing previous efforts in this journal and elsewhere to chronicle the history of the U.S. national laboratories and similar homes of Big Science abroad. Most importantly, the article communicates an alternative interpretative perspective on the institutional change of Big Science labs, consciously and consistently keeping its analysis at a micro level and emphasizing the incremental small-step changes of local actors in their everyday negotiations and deliberations. Not at all disqualifying or seeking to replace historical accounts framed with reference to macro developments of grand long-term change in science and science policy at the end of the previous century, but rather seeking to complement them, this article contributes with a worm's-eye view on change and advances the argument for a further exploration of such viewpoints in the historical analysis of institutional transformation in science.

KEY WORDS: synchrotron radiation, SSRP, SSRL, SLAC, SPEAR, U.S. national labs

The SLAC National Accelerator Laboratory is a dual-mission U.S. national laboratory for particle physics/particle astrophysics and so-called photon science.¹ It was founded in 1962 as a single-mission, single-machine U.S. national lab for high energy physics (HEP, synonymous with particle physics), under the supervision of the United States Atomic Energy Commission (AEC), and the original 3 km linear accelerator (linac) started operation in 1966. Since then, SLAC has built and run several machines for HEP, and importantly, undergone a gradual transformation from a single-mission lab to a multipurpose center dominated by its service to the scientific communities utilizing synchrotron radiation and free electron laser for atomistic studies of matter (photon science). SLAC operates two photon science user facilities: the Stanford Synchrotron Radiation Lightsource (SSRL), on the SPEAR 3 (Stanford Positron-Electron Accelerator Ring 3) storage ring, and the Linac Coherent Light Source (LCLS) free electron laser (FEL) facility that is a recent (twenty-first-century) extension of the original 1960s SLAC linac.² The particle astrophysics division of SLAC is the second major part of the laboratory, and

1. At its founding and during the time period covered in this article, SLAC was an acronym for the Stanford Linear Accelerator Center. The name was changed in 2007 to SLAC National Accelerator Laboratory, with the intention to better reflect the lab's current activities as well as keeping the well-known word "SLAC" (commonly pronounced "slack") in the name.

2. Until 2008, the acronym SSRL spelled out "Stanford Synchrotron Radiation Laboratory," which is also the meaning of the acronym in the remainder of this article, since it only covers the period until 1992.

runs the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC) jointly with Stanford University.

The transformation of SLAC has occurred in small steps, originating in the early 1970s exploitation of synchrotron radiation from the then state-of-the-art storage ring for HEP—SPEAR—in what is commonly referred to as parasitic mode. The term parasitic is widely used to designate the use, foremost in the 1960s and 1970s, of HEP machines for synchrotron radiation experiments in several countries in the Northern Hemisphere. The word is meant to indicate that these machines were designed, built, and run solely for HEP experiments and used for synchrotron radiation only as an auxiliary and unplanned, yet (given the conditions) a high-performing and productive activity. Typically, parasitic synchrotron radiation enterprises were completely dependent on the goodwill of those high energy physicists and accelerator physicists who used and operated the machines and therefore were in complete control over technical performance and, by extension, the actual quality and characteristics of the radiation. The case under study here is an archetypal example of this.

Parasitic use of HEP machines largely ceased in the late 1970s and early 1980s when purpose-built synchrotron radiation sources emerged as more powerful and reliable alternatives and, simultaneously, the forefront of HEP migrated to new accelerator machines, leaving free time on storage rings that were then taken over by synchrotron radiation laboratories. The latter was the case at SLAC, where in the late 1970s and thereafter, the Stanford Synchrotron Radiation Project (SSRP, in 1977 renamed the Stanford Synchrotron Radiation Laboratory, SSRL), formally an independent user group at SLAC, was granted dedicated time to use SPEAR.³ In the late 1980s SPEAR was deserted by the SLAC HEP program and taken over completely by SSRL. In 1992 SSRL became a division of SLAC, which then ceased to be a single-mission lab. In 2008 the last HEP machine at SLAC, the PEP-II (Positron-Electron Project II), was closed, and in 2009 the LCLS opened for experiments. In the early 2000s the SPEAR ring got a massive upgrade and is now called SPEAR 3, and it is still operating thirty-three independent experimental stations, serving approximately 1,700 users annually.⁴ In light of these recent developments,

3. In this article, SSRP is used as the name of the lab when describing events before the name change on October 22, 1977; SSRL is used for all episodes thereafter.

4. Stanford Synchrotron Radiation Lightsource, "About the Stanford Synchrotron Radiation Lightsource," www-ssrl.slac.stanford.edu/content/about-ssrl/about-stanford-synchrotron-radiation-lightsource (accessed 27 May 2014).

SLAC can be said to have completed its long-term transformation from a HEP lab to primarily a photon science lab, although some HEP activities remain.

This article chronicles the first twenty years of synchrotron radiation activities at SLAC, ending with the incorporation of SSRL into the SLAC organization. Analyzing the status and position of synchrotron radiation as a peripheral but gradually growing experimental activity at SLAC, the article provides a deeper understanding of the overall transformation of the lab, and its causes and mechanisms. The article thus documents an important piece of modern science history that arguably has explanatory value for broader scholarly interest in the history of the U.S. national laboratories and their transformations from the 1970s on, and for the wide historical context of changing dynamics of science and science policy over the course of the second half of the twentieth century. In relation thereto, the article also has another, more profound purpose: to contribute to the continuing conceptual discussion of what change in science means, and how it is brought about.

The exploration of the dynamic interplay of macro and micro structures in science policy, science organization, and the development of scientific fields has been curtailed by a conceptual division of macro and micro perspectives on institutional change (in science and elsewhere), and created a shortage of systematic explorations of how local small-scale change relates to transformations on a structural or systemic level. The history of science and science policy in the second half of the twentieth century has too often been framed only with reference to grand structural transformations, by which a Cold War logic of superpower competition in foremost nuclear energy and weaponry, but also several other realms, was replaced by a new social contract for science characterized by globalization and grand challenges related to disease and ecological and social sustainability.⁵ As part of this development, two complementary shifts in the priorities of U.S. national science policy have been identified: the relative decline of interest in HEP, which also ultimately led to the collapse of

5. Olof Hallonsten and Thomas Heinze, "Institutional Persistence through Gradual Adaptation: Analysis of National Laboratories in the USA and Germany," *SPP* 39, no. 4 (2012): 450–63; Daniel Kevles, "Big Science and Big Politics in the United States: Reflections on the Death of the SSC and the Life of the Human Genome Project," *HSPS* 27, no. 2 (1997): 269–97; Hallam Stevens, "Fundamental Physics and Its Justifications, 1945–1993," *HSPS* 34, no. 1 (2003): 151–97; Ann Johnson, "The End of Pure Science: Science Policy from Bayh–Dole to the NNI," in *Discovering the Nanoscale*, ed. Davis Baird, Alfred Nordmann, and Joachim Schummer (Amsterdam: IOS Press, 2004), 217–30; Michael Riordan, "The Demise of the Superconducting Super Collider," *PiP* 2 (2000): 411–25; Catherine Westfall, "Surviving the Squeeze: National Laboratories in the 1970s and 1980s," *HSNS* 38, no. 4 (2008): 475–78.

the Superconducting Super Collider project and the closing of several accelerator facilities in the national laboratory system, and the concurrent growth in societal and economic interest in materials science and the life sciences, which culminated with the doubling of the National Institutes of Health (NIH) budget and the launch of the National Nanotechnology Initiative (NNI) during the Clinton administration.⁶ The internal restructuring of HEP beginning in the 1960s, which forced a redirection of the national funding policy for the field from several complementary sites and facilities across the country to one or a few prioritized sites and facilities (referred to by some as the transition from Big Science to Megascience) fed into this change in policy priorities and contributed to creating a mission vacuum in the national laboratories system that posed a threat to their survival.⁷ However, a concurrent rise of alternative uses of large scientific facilities, most evidently the use of accelerators, reactors, and other large facilities for experimental work in the materials and life sciences, provided a solution to the crisis for several of the labs. On the level of the system of national laboratories, it is possible to identify a broad and sweeping, albeit slow and gradual, redirection of priorities that mirrors the aforementioned global transformation of science and science policy away from (nuclear) physics and toward health and sustainability.⁸

At SLAC, these developments played out in the following way, briefly sketched: Facing intensifying competition from, above all, the Fermi National Accelerator Laboratory (Fermilab) but also from facilities abroad, SLAC ingeniously renewed its experimental HEP program for as long as possible, with the PEP-II representing the last major effort, commissioned in the mid-1990s. Simultaneously, the size of the SLAC site imposed restrictions on development possibilities, not least in the 1990s and thereafter, when the proposed machines

6. On the relative declining interest in HEP, see Robert Crease, “Quenched! The ISABELLE Saga, II,” *PiP* 7 (2005): 404–52; Riordan, “Demise” (ref. 5); Westfall, “Surviving” (ref. 5). On the growing interest in materials and life sciences, see Harold Varmus, *The Art and Politics of Science* (New York: W. W. Norton, 2009), 144–45; W. Patrick McCray, “Will Small be Beautiful? Making Policies for Our Nanotech Future,” *History and Technology* 21 (2005): 177–203.

7. On the transition from Big Science to Megascience, see Lilian Hoddeson, Adrienne Kolb, and Catherine Westfall, *Fermilab: Physics, the Frontier & Megascience* (Chicago, IL: University of Chicago Press, 2008). On the threats to survival in the national laboratories system, see Westfall, “Surviving” (ref. 5); Jack Holl, *Argonne National Laboratory 1946–96* (Chicago, IL: University of Illinois Press, 1997), 377–429.

8. Hallonsten and Heinze, “Institutional Persistence” (ref. 5); Catherine Westfall, “Institutional Persistence and the Material Transformation of the U.S. National Labs: The Curious Story of the Advent of the Advanced Photon Source,” *SPP* 39, no. 4 (2012): 439–49.

were the size of the SSC and the Next Linear Collider (NLC), and simply too big for SLAC to host. Meanwhile, the synchrotron radiation activities at SLAC grew continuously and proved themselves scientifically throughout the 1970s, 1980s, and 1990s, gradually taking over the SPEAR storage ring. When in 1990 SPEAR was deserted completely by HEP and became fully dedicated to synchrotron radiation, a vibrant user community stood ready to utilize its enhanced performance and also plan for the next steps of developing their experimental activities at SLAC. The old SLAC linac became the focus of their attention when in the mid-1990s linac-based so-called free electron lasers (FELs) emerged as the promise of the future in the development of experimental use of synchrotron radiation. After the closing of the PEP-II in 2008 and the opening of the LCLS in 2009, SLAC now only runs accelerator facilities for photon science (and accelerator research) and not for HEP, and so the transformation is in a sense completed.⁹ The transition was somewhat eased by the opportune partial and gradual migration of the HEP activities at SLAC into the field of particle astrophysics, beginning in the 1990s, which allowed large groups of in-house scientists (in theoretical as well as experimental HEP) to reorient their activities away from experimental work on facilities on-site and toward the larger U.S. and international efforts in particle astrophysics and cosmology, including the launch of satellite-based telescopes in collaboration with the National Aeronautics and Space Association (NASA) and others.¹⁰

Thus can the fifty-year history of SLAC be told, if explanations are kept on the macro or meso level and the historical narrative is framed by structural change in global and national (U.S.) science and science policy priorities. Such sweeping systemic change is indeed both empirically provable and conceptually alluring. But it is limited in its explanatory power, since it only accounts for change in structural perspective, and fails to acknowledge micro-level change driven by creative and entrepreneurially minded scientists and policymakers at the local university and lab level, who negotiate change in small incremental steps and who do not necessarily lack bold visions and long-term objectives, but whose aims and objectives typically are on the level of individual career achievement or the success and advancement of research projects or programs within groups or departments.

9. Olof Hallonsten and Thomas Heinze, "From Particle Physics to Photon Science: Multidimensional and Multilevel Renewal at DESY and SLAC," *SPP* 40 (2013): 591–603.

10. Neil Calder, "Spectrum of Discovery," *Symmetry* 2, no. 5 (2005): 10–15.

This article seizes upon the disconnect between macro- and micro-level framings and explanations of institutional change, not in an attempt to disqualify or replace the macro perspective but to complement it with another type of contribution to historical studies of change in science that does not shy away from detail and complexity either in the use of material or in the discussion. Such a contribution requires the use of a dense narrative of multifaceted micro-level change to consistently argue that change is brought about not only in high-level policy shifts, but also by sequences of micro-level actions.

In analyzing these types of drivers of change, complexity and detail is therefore a virtue and not a vice. What the article's meticulously detailed historical analysis of lab-level change reveals is indeed that the analysis of the profound transformation of SLAC, a flagship U.S. national research lab and an important part of the postwar mobilization of science and technology for progress, cannot be reduced to one straightforward explanation. While clearly situated in a historical context of overall alterations of policy priorities and ambitions, the transformation of SLAC was not only (or even primarily) driven by federal policymaking and central priority-setting in national (or international) scientific communities, but also by the everyday debates, conflicts, and negotiations among directors, managers, research leaders, scientists, and technicians at SSRP/SSRL, SLAC, Stanford University and its various departments and schools, the National Science Foundation (NSF), the DOE, and other organizations in science and science policy that benefited from the existence and well-being of the synchrotron radiation activities at SLAC. In emphasizing this, and making the micro perspective the key analytical frame, the article connects to other recent studies of labs under change, which similarly employ chiefly a micro perspective. Park Doing, for example, in his study of the transformation of the Cornell particle accelerator laboratory into a synchrotron radiation source, makes a strong case for arguing that while change on the throne of Western science in the late twentieth century from (particle) physics to life science was indeed a revolution, a closer look at the loci of this revolution reveals that it was gradual and occurred through small-scale "epistemic politics" rather than macro-level discontinuous shifts.¹¹ Such an interpretation of late twentieth-century history of science deserves a prominent place alongside macro-level analyses of changes in the same time period.

11. Park Doing, *Velvet Revolution at the Synchrotron: Biology, Physics, and Change in Science* (Cambridge, MA: MIT Press, 2009).

As the title suggests, the parasitic status of the synchrotron radiation activities at SLAC is of special interest here. Organizationally, the parasitic status ended in 1992 when SSRL was incorporated into the SLAC organization and the SSRL director was promoted to SLAC associate lab director. But there are other meanings of parasitic—the synchrotron radiation program was allowed half-time dedicated operation of the SPEAR storage ring in 1979 (and shorter dedicated runs, counted in days, had been done even earlier), and in 1990 SPEAR was turned over to full-time use for synchrotron radiation, which means that in a technical or scientific sense, the parasitism ended before 1992. This indicates, once more, that there are other dimensions to the change of SLAC than what is seen in organization charts or from the viewpoint of national or international science and science policy. It is the main purpose of this article to explore the alternative, micro level of change in an attempt to add another dimension to the analysis of long-term institutional transformation in science.

The article draws on four types of sources: (1) SSRL Activity Reports, published in 1973 and thereafter and containing annual accounts on the development of SSRL, its experimental program, and its relationship to SLAC; (2) material from the SLAC Archives; (3) some secondary literature; and (4) complementary material from interviews conducted in the fall of 2007 for use in a previously published study of synchrotron radiation at SLAC with a slightly different perspective, as well as some complementary interviews conducted in the spring of 2013.¹²

THE STANFORD SYNCHROTRON RADIATION PROJECT

Prehistory

The German-American physicist Wolfgang Kurt Hermann “Pief” Panofsky, a German immigrant in 1934, gained tenure at Stanford University’s physics department in 1951 after having worked with experimental HEP under future Nobel laureate (1968) Luis Alvarez at the Lawrence Berkeley National Laboratory (LBL).¹³ At Stanford, a major innovation in accelerator technology had

12. Olof Hallonsten, “Small Science on Big Machines: Politics and Practices of Synchrotron Radiation Laboratories” (PhD dissertation, Lund University, 2009).

13. Wolfgang Panofsky, *Panofsky on Physics, Politics, and Peace: Pief Remembers* (Dordrecht: Springer, 2007), 17–59; Michael Riordan, *The Hunting of the Quark: A True Story of Modern Physics* (New York: Touchstone Books, 1997).

occurred in 1937 with the invention of the klystron, a device that greatly enhanced the charging of particles with energy in accelerators.¹⁴ In 1947 the accelerator group at the Stanford University Microwave Laboratory completed their first linac, three feet long, soon to be followed by linacs of increasing size in the following years, and in 1953 the Stanford High Energy Physics Laboratory (HEPL) was founded with Panofsky as its first director.¹⁵ The growing sizes of the linacs triggered a reach for funding beyond the campus, and at the time, the federal checking account for fundamental physics in the United States seemed almost unlimited, with machines of bigger and bigger size being built across the system of national laboratories, at LBL, Argonne National Laboratory (ANL), and Brookhaven National Laboratory (BNL).¹⁶

The largest linacs on campus had been funded largely by the AEC, and with good prospects of federal funding, the Stanford high energy physicists could not resist making bold plans for the next step.¹⁷ The Stanford professor and eventual Nobel laureate in physics (1961) Robert Hofstadter originally came up with Project M (where “M” stood for “Monster” or “Multi-GeV”), a two-mile (3 km) construction that would give Stanford physicists access to “a frontier of physics unapproachable by any other means now considered feasible,” as Hofstadter reportedly told the Stanford president. Hofstadter and Panofsky started working on a proposal together with Professor Edward Ginzton, who had participated in the development of the klystron and contributed to the earliest accelerator projects at Stanford.¹⁸ The proposal for the Project M accelerator was submitted simultaneously on April 18, 1957, to three funding agencies: the AEC, the NSF, and the Department of Defense (DOD).¹⁹ While the Stanford University administration strongly

14. Andrew Sessler and Edmund Wilson, *Engines of Discovery: A Century of Particle Accelerators* (Hackensack, NJ: World Scientific, 2007), 36.

15. Douglas Dupen, *The Story of Stanford's Two-Mile-Long Accelerator* (Stanford, CA: Stanford Linear Accelerator Center, 1966), 39, 46–48; Peter Galison, Bruce Hevly, and Rebecca Lowen, “Controlling the Monster: Stanford and the Growth of Physics Research, 1935–1962,” in *Big Science: The Growth of Large-Scale Research*, ed. Peter Galison and Bruce Hevly (Stanford, CA: Stanford University Press, 1992), 63. The HEPL changed its name in 1990 to Hansen Experimental Physics Laboratory, with the acronym unchanged.

16. Peter Westwick, *The National Laboratories: Science in an American System 1947–1974* (Cambridge, MA: Harvard University Press, 2003), 183.

17. Galison et al., “Controlling the Monster” (ref. 15), 65.

18. Dupen, *Story* (ref. 15), 52; quote from Galison et al., “Controlling the Monster” (ref. 15), 65.

19. Wolfgang Panofsky, “SLAC and Big Science: Stanford University,” in Galison and Hevly, *Big Science* (ref. 15), 131–32; Dupen, *Story* (ref. 15), 56.

backed the plans of Project M, it was evident that the project was far too big to be hosted on campus and completely within the university organization. The congressional committee overseeing the AEC, which had emerged as the likely funder of Project M after the Eisenhower administration declared it the “custodian agency” for HEP in late 1957, also “questioned whether public funds of such magnitude could justifiably be allocated to a private university,” and thus, as an amendment to the AEC’s decision in favor of the project, it was suggested that it be established as a national laboratory and thereby become a national user facility.²⁰ Hofstadter, who opposed the idea of making the new accelerator facility a federal laboratory and argued that the giant machine be exclusively a facility for Stanford University physicists, left the project in 1961, before groundbreaking. This disagreement was the original source of the division between SLAC and Stanford physicists that continued for several decades and reportedly caused strained relations between the lab and the university.²¹

In 1959, after reviews by an ad hoc committee, both the AEC and the White House declared support for Project M, which by then had been renamed SLAC, and on September 15, 1961, Congress authorized the project at an estimated cost of \$114 million.²² Groundbreaking took place in July 1962, and in November 1966 the first HEP experiments were conducted with the accelerator and the two endstations.²³ The work at SLAC in the late 1960s included the first experimental confirmations of the existence of quarks by the group led by Richard Taylor, who was subsequently awarded the 1990 Nobel Prize in physics for this work (shared with Jerome Friedman and Henry Kendall at the Massachusetts Institute of Technology [MIT]).²⁴ Panofsky had been the obvious choice for SLAC director, and remembers being “often asked, after the initial completion of SLAC construction, how long the laboratory could productively operate,” and gave as his “standard answer”: “Ten years, unless someone produces a good idea.”²⁵

20. Rebecca Lowen, *Creating the Cold War University: The Transformation of Stanford* (Berkeley: University of California Press, 1997), 179.

21. Riordan, *Hunting* (ref. 13), 125.

22. Panofsky, “SLAC and Big Science” (ref. 19), 132.

23. *Ibid.*; Dupen, *Story* (ref. 15), 57, 58, 114.

24. Riordan, *Hunting* (ref. 13), 135.

25. Panofsky, *Panofsky* (ref. 13), 126.

The SPEAR Storage Ring

The MIT-trained physicist Burton Richter had arrived at the HEPL in the late 1950s to start working on new accelerator concepts, especially storage rings that would enable the colliding of beams head-on and (theoretically) double the turnout of experiments compared to beams from linacs hitting a stationary target.²⁶ Accounts differ on where the most prominent work to develop the storage ring concept from idea to reality across the United States beginning in the 1950s really took place, but both Stanford and Harvard physicists were reportedly deeply involved.²⁷ According to SLAC director Panofsky, it was the Stanford group of Richter, Gerard K. O'Neill, and W. C. Barber that “first had the courage” to actually design and build storage rings, and although there were scientific and engineering reservations, SLAC adopted their ideas and backed a proposal to build an electron-positron storage ring on-site.²⁸ A funding proposal was submitted to the AEC in 1964 but not approved, due to other priorities at the national level, not least the preparation for the National Accelerator Laboratory (NAL) in Illinois, i.e., what would eventually become Fermilab. SLAC was furthermore judged already comparably well-equipped.²⁹ A competing proposal for a storage ring was also submitted by the Cambridge Electron Accelerator (CEA) group at Harvard, but the two labs were encouraged by the AEC to collaborate rather than compete, and worked on a joint proposal throughout the remainder of the 1960s. In spite of the promises of this project, however, with a tightening of budgets and an increased focus of federal resources for HEP on the new laboratory in Illinois, SLAC’s plans for a storage ring seemed to be fizzling out—and with it, SLAC physicists argued, also the U.S. global lead in particle physics. A creative solution, reached by an agreement between SLAC director Panofsky and the AEC in 1970, redefined SPEAR from a separate construction project to part of the general equipment budget, and enabled its construction in spite of resistance in Washington. Partly as a result of this maneuver, construction costs for SPEAR were lowered from the \$15.5 million estimated in 1964 to an eventual \$5.27 million. The construction of SPEAR took a mere twenty months, and once completed, the ring took only two weeks of commissioning to start

26. Riordan, *Hunting* (ref. 13), 246.

27. Elizabeth Paris, “Lords of the Ring: The Fight to Build the First U.S. Electron-Positron Collider,” *HSPS* 31 (2001): 355–80, on 359.

28. Panofsky, *Panofsky* (ref. 13), 56–58.

29. Riordan, *Hunting* (ref. 13), 247–48.

working.³⁰ Particle physics experimentation on SPEAR began in 1973, and already a year later came the ring's first significant success, namely the events in the fall of 1974 that became known as the November Revolution and set HEP on a new route (see below).³¹ Somewhat ironically, given the funding obstacles, the SPEAR ring became "one of the greatest monetary bargains ever achieved on behalf of the American people in postwar particle physics," and taking into account also the contributions to the development of synchrotron radiation science and technology, the SPEAR accelerator indeed rose to become one of the most important—and cost effective—machines in accelerator history.³²

The First Ideas for a Stanford Synchrotron Radiation Project

Synchrotron radiation was a well-known phenomenon in the HEP community by the late 1960s. Accelerating particles along circular paths inevitably makes these particles lose energy in the form of synchrotron radiation, and this energy loss was (and is) a nuisance and an obstacle on the way to higher energy particle collisions, large enough to have engendered significant interest in the field. Simultaneously, the radiation had a documented high intensity that made it potentially useful, and this had also been proven in experimental work at, among other places, the Deutsches Elektronen-Synkrotron (DESY, German Electron Synchrotron) laboratory in Hamburg, Germany, and at the Synchrotron Radiation Center (SRC) at the University of Wisconsin, Madison, where the Tantalus ring opened for use in 1968. Tantalus was an abandoned storage ring for accelerator R&D that had been converted into a dedicated synchrotron radiation source, and produced high-quality radiation in the ultraviolet range for a number of scientific applications until its closing in 1986.³³ With the opening of Tantalus, the expectation had been proven right that storage rings enabled a big jump in the usefulness of synchrotron radiation: while synchrotrons emitted flickering and unstable light flashes, storage rings provided continuous beams.

In a 1968 letter to Panofsky, Stanford engineering professor William Spicer inquired about the "long-term interest" in using synchrotron radiation from

30. Paris, "Lords of the Ring" (ref. 27), 371–80.

31. Riordan, *Hunting* (ref. 13), 245; Panofsky, *Panofsky* (ref. 13), 120.

32. Paris, "Lords of the Ring" (ref. 27), 356.

33. David Lynch, "Tantalus, a 240 MeV Dedicated Source of Synchrotron Radiation, 1968–1986," *Journal of Synchrotron Radiation* 4 (1997): 334–43, on 334–35.

SPEAR, a utilization that could “open up new fields for solid state physics and chemistry.”³⁴ The letter was followed by recurrent informal contacts between the two and Burton Richter, head of the SPEAR project. When construction of SPEAR started in August 1970, the design included a pipe on the vacuum chamber where synchrotron radiation could later be extracted.³⁵ Richter remembers being convinced of the potential of synchrotron radiation, and decided to prepare SPEAR for it: “Doniach and Spicer both came to me and they said basically, not these words but this is the way I remember it: ‘If you’ll let those X-rays out, we will revolutionize condensed matter physics.’”³⁶ As long as the intervention to extract synchrotron radiation from SPEAR did not require any “major modification of the storage ring magnet system” and did not rise above “a few thousand dollars” in cost, the beam pipe would be paid by the ordinary SPEAR construction budget. Duly informed of the plans, Panofsky had agreed to proceed “on a short run” and discuss long-term plans with Spicer himself.³⁷

In early 1970, a group of Stanford faculty members had been formed to discuss the prospects of future utilization of synchrotron radiation from SPEAR, including Doniach and Spicer as well as Arthur Bienenstock and John Baldeschwieler.³⁸ In early 1971, the group started discussions with the NSF that eventually led to the preparation of a funding proposal. Simultaneously, a postdoc at Stanford’s Center for Materials Research (CMR), Dan Pierce, was set to work with members of the SLAC staff to assess the possibilities and estimate the costs of attaching one port for synchrotron radiation to SPEAR, to which a small facility with three beamlines could be attached. During 1971, discussions on campus also produced a number of suggestions regarding promising areas of experimental utilization of synchrotron radiation from SPEAR.³⁹

34. Quote from Professor William Spicer’s letter to SLAC director Panofsky, dated 18 Jun 1968 and reprinted in Stanford Linear Accelerator Center, *Celebrating Forty Years: A Photo History* (Menlo Park, CA: Stanford Linear Accelerator Center, 2002), 24.

35. “Brief Chronological History of the Conception, Design, Construction and Initial Operation of SSRP,” SSRP Activity Report May 1973–Dec 1974.

36. Burton Richter, interview by author, Menlo Park, CA, 9 Nov 2007.

37. Burton Richter, “Discussion with Professor William Spicer on a Synchrotron Light Facility Associated with SPEAR,” Jun 1970, SLAC Archives, Richter series 7, Box 1, Folder 1.

38. “Brief Chronological History” (ref. 35).

39. Sebastian Doniach, “Short History and Current Status of the Stanford Synchrotron Radiation Project,” 19 Jan 1973, SLAC Archives, Richter series 7, Box 1, Folder 2.

The Proposal

The success of the Tantalus ring in Madison, Wisconsin, in the ultraviolet range, and the prospects of extending the use of synchrotron radiation into several other areas by producing soft and hard X-rays, had led the NSF to organize an evaluation of the prospects for a national synchrotron radiation laboratory in 1970. In 1971 a call for proposals was sent out, specifically inviting project proposals that would make radiation available in the X-rays regime.⁴⁰

The Stanford group, led by Spicer and Doniach, submitted their proposal on December 2, 1971, requesting a sum of \$500,000 to build a “parasitic” synchrotron facility at SLAC for local users.⁴¹ The proposal stated that the exploitation of synchrotron radiation from SPEAR “presents a unique opportunity . . . to the study of the structure of matter ranging from physics experiments, on the atomic scale, up to the development of improved techniques of medical diagnostic radiology.” The “unique” opportunity was due to SPEAR’s high energy (3 Giga electron Volts, GeV) and current (250 mA), unmatched by any other accelerator used for producing synchrotron radiation at the time.⁴² The proposal notes that although operation of SPEAR was completely in the hands of the SLAC HEP program, synchrotron radiation users would be able “to coordinate their experiments with the storage ring parameters” as long as “experiments are planned well in advance.” The proposal described four classes of experiments: a medical-diagnostic application using conventional medical X-ray scans with significant contrast enhancement; X-ray Photoemission Spectroscopy (XPS) for solid state physics, materials science, inorganic and organic chemistry, with unprecedented resolution; X-ray diffraction for biology, especially large proteins and polynucleotides, as well as for materials studies; and applications of Extended X-ray Absorption Fine Structure (EXAFS) spectroscopy that had recently been developed but whose real experimental usefulness was yet to be proven. The significantly enhanced performance expected in all of these areas would not be possible without SPEAR’s high energy and current.⁴³

40. Doniach, “Short History” (ref. 39).

41. *Ibid.*; “Brief Chronological History” (ref. 35).

42. Sebastian Doniach and William Spicer, “Stanford Synchrotron Radiation Project: A Proposal to the National Science Foundation to Set Up a Facility to Utilize Synchrotron Radiation from the SLAC Storage Ring for Experiments in Physics, Chemistry, Science of Materials and Medicine: Two Years for the Period from 1 April 1972–31 March 1974 in the Total Amount of \$538,102,” Nov 1971, SLAC Archives, 1999-002 series, Box 2/3, Folder 51.

43. Doniach and Spicer, “Stanford Synchrotron Radiation Project” (ref. 42).

Two other proposals were submitted to the NSF: the SRC hosting Tantalus proposed an expansion of their current activities, and the CEA group at Harvard University proposed converting a synchrotron accelerator to a storage ring for synchrotron radiation, since their funding for HEP work on the machine was to be cut as of June 1973.⁴⁴ As noted above, CEA had been one of the contenders for building a storage ring for HEP already in the early 1960s and had collaborated with Stanford and SLAC physicists on design work for a joint storage ring, in the hopes that this joint ring would be built at Harvard instead of SLAC. But the technical advantages of injections from the SLAC linac, and other major infrastructural assets available on the SLAC site, made the AEC's choice comparatively easy and the storage ring was eventually destined for SLAC.⁴⁵ In an attempt to rescue their machine, the Harvard team now proposed that it be converted to a synchrotron radiation source.

The Stanford proposal had some apparent competitive advantages, such as the active support of SLAC director Panofsky. In a February 17, 1972 letter to Howard Etzel at the Division of Materials Science at the NSF, Panofsky wrote, "SLAC is very enthusiastic about this proposal; we feel that not only does exploitation of SPEAR's synchrotron light open really unique new opportunities in medical science, physics, chemistry, and materials research, but it does so at minimum cost to the proponents."⁴⁶ On a site visit to SLAC on March 22, 1972, Dr. Paxton, Head of Materials Research at the NSF, toured SPEAR and was "impressed with its physical realness."⁴⁷ Nonetheless, it took the NSF over a year to make its decision, and so it was not until March 1973 that SSRP was granted the funding to start building a national user facility for synchrotron radiation at SPEAR. But the time in between was not a time of inactivity.

The Pilot Project

With the construction of SPEAR proceeding according to plan, and with a beam pipe attached to the ring, the group around Spicer and Doniach saw no reason to wait for the NSF decision on their proposal, but decided to go

44. Sebastian Doniach, "Note to Members of the Stanford Synchrotron Radiation Project, on the Status of Our Proposal with the NSF," 2 May 1972, SLAC Archives, Panofsky series IV, sub A, Box 5, Folder 6.

45. Paris, "Lords of the Ring" (ref. 27), 358–71.

46. Wolfgang Panofsky to Howard Etzel, 17 Feb 1972, SLAC Archives, Richter series 7, Box 1, Folder 1.

47. Doniach, "Note to Members" (ref. 44).

ahead and start a pilot project with internal Stanford University funding. In January 1972 the CMR authorized purchase of the ultra high-vacuum valve that was needed to extract radiation from the pipe at SPEAR, and soon thereafter, the Stanford Dean of Engineering granted the funds necessary to conduct a pilot project during the second half of 1972.⁴⁸ In June 1972 a proposal was submitted to the SLAC lab-operations committee to allow preliminary experimental work with XPS, for materials science, medicine, and biology experiments, between July 1 and December 31, 1972.⁴⁹ Construction of the experimental station began in July 1972, in a temporary building adjacent to the ring (the June 1972 proposal had proposed the use of a tent), made available by the SPEAR HEP team.⁵⁰ SLAC and the AEC granted the necessary formal approvals during the fall, and in December 1972 the SSRP was formally established as a project within the Stanford Department of Engineering. Sebastian Doniach was appointed director and William Spicer associate director, and an advisory Science Policy Board (SPB) was set up to ensure the quality of the scientific program, reporting directly to the president of Stanford and chaired by John Baldeschwieler. In November 1972, a supplementary proposal for initial experiments on high-resolution XPS was submitted to the NSF. It was granted funding of \$59,000 starting January 1, 1973.⁵¹

Toward a National User Facility

Although SLAC directors and senior scientists apparently showed enthusiasm for the scientific possibilities of the synchrotron radiation project, the relationship between the SSRP and its hosts was never to be other than truly parasitic. SLAC remained the flagship laboratory in the (still very high-profile and prestigious) federal U.S. HEP program, and despite the difficulties to fund SPEAR, the machine was the new great promise. The February 1972 letter from Panofsky to Howard Etzel at the NSF certainly praised the plans of the SSRP, but simultaneously affirmed the ground rules: SLAC to be a single-purpose HEP laboratory, meaning that “the scope of work” proposed by the SSRP “does not fit within the program from which we derive our support.”

48. Doniach, “Short History,” (ref. 39).

49. Sebastian Doniach et al., “Proposal to SLAC Lab-operations Committee to Conduct Preliminary Experiments on the SPEAR Synchrotron Radiation Port for the Period July 1, 1972–December 31, 1972,” n.d., SLAC Archives, Richter series 7, Box 1, Folder 1.

50. Doniach, “Short History” (ref. 39); Richter, interview (ref. 36).

51. Doniach, “Short History” (ref. 39).

The solution to this, wrote Panofsky, was to “consider this proposal along similar lines as we do a proposal by any other outside experimental user of SLAC facilities,” that is, SLAC routinely “makes available particle beams and major facilities to qualified users throughout the country without charge” and would be willing to do so also in this case. But the use of SPEAR synchrotron radiation “will be ‘parasitic’; this means that in setting up the SPEAR schedule this program will not be given primary consideration.”⁵²

Panofsky was of course aware that the SSRP and the NSF envisioned not just a temporary, exploratory synchrotron radiation project at SPEAR, but rather an eventual national resource, open for external user groups on a regular basis. Such an enterprise would require another level of formalized organization for the coexistence of HEP and synchrotron radiation on SPEAR, both technically and administratively, and so Panofsky appointed Gerry Fischer, a SLAC scientist with a background in solid state physics, to thoroughly review the SSRP proposal to the NSF and the prospects of establishing a long-term synchrotron radiation program at SPEAR. The resulting study report (hereafter the Fischer study) cited the “unique possibilities” of synchrotron radiation produced by storage rings “in a wide variety of fields” and a growing interest across the United States, but also noted that expanded utilization of the highly desirable X-ray radiation for a wide range of applications required larger construction efforts, “very rigid” safety measures, and a support and maintenance infrastructure on a level previously unseen at synchrotron radiation facilities—in sum, a rather ambitious and costly installation. Noting that the newness of the field meant that “the long-term demand for the facility cannot be predicted very reliably at this time,” the study suggested that the SSRP should be realized in “a phased, step-by-step development . . . in which any expansion of the original facility would be undertaken only after the need had been well demonstrated.”⁵³ In other words, the Fischer study recommended that SLAC allow the creation of a national user facility for synchrotron radiation at SPEAR, but by way of a cautious step-by-step development.

During 1972 a number of scientists outside Stanford had submitted expressions of interest in experimental work at the planned SSRP. The newly appointed SSRP SPB recommended that access be provided free of charge,

52. Panofsky to Etzel, 17 Feb 1972, SLAC (ref. 46).

53. Gerry Fischer, “Study of a Possible Construction Program of a National Synchrotron Radiation Facility at the SLAC Electron-Positron Storage Ring (SPEAR),” Dec 1972, SLAC Archives, 1999-002 series, Box 2, Folder 51.

that all operation costs should be covered by the NSF grant(s), and that an organized peer-review-based system be established for the assessment of experimental proposals and allocation of beamtime.⁵⁴ The regulations were laid down in an “Outside Users Document,” dated November 1972 and signed by Doniach, Spicer, Panofsky, and W. Massy, the Stanford University vice provost for research. It reiterated the basic premise that the SSRP not “in any way interfere” with HEP research on SPEAR, and established that experimental time should be provided to outside users free of charge and solely on the basis of scientific merit and technical feasibility. A committee composed of external experts was to assess proposals and recommend allocation of time to the SSRP director, who would make the formal decision.⁵⁵

The NSF Decides and the Project Starts

In February 1973 the NSF’s National Review Committee for Synchrotron Radiation made site visits to Harvard University, the University of Wisconsin, and Stanford University, and asked the three contenders to revise their proposals in accordance with a new request that the future national synchrotron radiation laboratory aim specifically at providing radiation in the X-ray range.⁵⁶ The revised Stanford proposal was submitted on February 2, 1973, and called for an estimated total cost of \$1,272,000 for the period June 1, 1973 to August 31, 1975.⁵⁷ The Wisconsin proposal was not revised—the SRC kept its focus on ultraviolet radiation and had the advantage of already operating the well-functioning Tantalus machine. Consequently, the SRC was also awarded an NSF grant to continue operations in this range throughout the 1970s, which meant that the competition for the X-rays synchrotron radiation source stood between the SSRP and the CEA.⁵⁸

The Harvard and Stanford proposals showed remarkable differences. Whereas the SSRP quite modestly proposed to conduct parasitic operation with one beam port at the SPEAR storage ring, at a cost of \$500,000 for two years, the CEA team’s plans included rebuilding their whole ring into a fully

54. John D. Baldeschwieler, chairman of the SSRP science policy advisory board, to Richard W Lyman, Stanford president, 22 Mar 1973, SLAC Archives 1999-002 series, Box 3, Folder 68.

55. “Outside Users at the Stanford Synchrotron Radiation Project: A Statement of Intention about General Policy,” n.d., SLAC Archives, Richter series 7, Box 1, Folder 2.

56. “Brief Chronological History” (ref. 35).

57. Sebastian Doniach and Bill Spicer, “Memo to Members and Friends of the SSRP,” 15 Mar 1973, SLAC Archives, Richter series 7, Box 1, Folder 2.

58. Lynch, “Tantalus” (ref. 33), 336.

dedicated synchrotron radiation source, with wigglers (see below) and several beamlines, all amounting to over \$4 million during a thirty-six-month period.⁵⁹ The choice for the NSF was, therefore, to fund either an entire dedicated source at Harvard, which probably in practice would mean a commitment for a longer period of time than the thirty-six months cited in the proposal; or a small-scale, parasitic operation on a ring already in use, with a potential of gradual expansion if the research turned out to be successful. Importantly, the parasitic operation of SPEAR relieved the NSF of any responsibility for machine operation and maintenance, and furthermore, location of the SSRP at SLAC secured operations stability and access to top-class accelerator physicists and technicians. In the words of co-applicant Sebastian Doniach, “the machine ran with DOE money so the NSF didn’t have to pay for the machine. That was the big deal.”⁶⁰

In a March 15, 1973 memo to “Members and Friends of the SSRP,” Doniach and Spicer reported the happy news that the NSF committee unanimously had recommended the SSRP proposal and that the NSF now “is anxious that we should try and build up the facility as expeditiously as possible.”⁶¹ The CEA was, simultaneously, given an effective shutdown decision.⁶² An April 1973 amended proposal to the NSF outlined “Phase I” of SSRP, consisting of five independent experimental stations on one beamline, and specified the design and layouts of buildings, beam and vacuum systems, and instruments. It also laid out the principles for proposal review and the scheduling of experimental time: The disciplinary breadth of the expected user community called for a heterogeneously composed proposal review panel appointed by the director, complemented by external referees evaluating scientific quality, and the

59. “Research Proposal Submitted to the National Science Foundation by the Executive Committee of the Cambridge Electron Accelerator, Harvard University, Cambridge, Massachusetts, 02138, for the Establishment of the Cambridge Electron Accelerator as a National Facility Dedicated to the Use of Synchrotron Radiation for Research in Physics, Chemistry and Biology,” dated 1972, received through personal communication from Herman Winick; “Stanford Synchrotron Radiation Project: A Proposal to the National Science Foundation to Set Up a Facility to Utilize Synchrotron Radiation from the SLAC Storage Ring for Experiments in Physics, Chemistry, Science of Materials and Medicine: Two Years for the Period from 1 April 1972–31 March 1974 in the Total Amount of \$538,102,” Nov 1971, SLAC Archives, 1999-002 series, Box 2/3, Folder 51; Doniach and Spicer, “Stanford Synchrotron Radiation Project” (ref. 42); Sebastian Doniach et al., “Early Work with Synchrotron Radiation at Stanford,” *Journal of Synchrotron Radiation* 4 (1997): 380–95, on 380.

60. Sebastian Doniach, interview by author, Stanford, CA, 19 Oct 2007.

61. Doniach and Spicer, “Memo” (ref. 57).

62. Lynch, “Tantalus” (ref. 33), 336.

assessment of technical feasibility (including vacuum and radiation safety) by SSRP and SLAC staff. Every accepted proposal was to be assigned a number of hours scheduled within a specific block of time, and the overall schedule should be coordinated with the cycles of SPEAR operation. The formal organizational status of the SSRP would be an independent laboratory within the Hansen Laboratories at Stanford University, with the director of the SSRP reporting directly to Stanford's vice provost for research.⁶³

The NSF made its formal funding decision in April 1973, granting \$750,000 to the SSRP, and construction work started in June 1973. On July 6, 1973, at 10:42 AM, synchrotron radiation first emerged out of SPEAR.⁶⁴ The design of buildings and instruments proceeded throughout July and August, with the aim of making a first run for external users during the May–June 1974 SPEAR cycle that immediately preceded the planned SPEAR upgrade program, which would take three months of complete shutdown and increase energy levels from 2.4 GeV to 3 GeV (and rename the ring SPEAR 2).⁶⁵

In the meantime, the pilot project proceeded toward its first experimental runs. On September 27, 1973, the XPS experimental station was placed into operation, and on November 10, 1973, at 4:13 PM, the first XPS spectra was obtained with synchrotron radiation from SPEAR. The main construction work of SSRP “Phase 1” took place between November 1973 and May 1974, with critical work on the vacuum tube of SPEAR carried out during scheduled shutdowns. On May 13, 1974, the first beam arrived at an SSRP beamline, and on June 4, the first regular data taking by outside users began. By the time of the end of the May–June 1974 SPEAR run, on July 3, 1974, data had been taken on all five experimental stations. As expected, demand was high. In the SSRP Activity Report for the period May 1973 to December 1974, director Sebastian Doniach reported that in the period, 29 proposals from 19 groups totaling 55 individuals “from government, private industry, and university research laboratories” had been granted access. This big turnout, writes Doniach, “is evidence of the very considerable potential” for synchrotron radiation in the X-ray range in “studies of condensed matter, atomic and

63. “Amendment to the Stanford Synchrotron Radiation Project Proposal (Original Proposal Submitted December 1971) to the National Science Foundation for the Period 1 June 1973 through 31 May 1975,” April 1973, SLAC Archives 1999-002 series, Box 2/3, Folder 49.

64. “Brief Chronological History” (ref. 35).

65. Herman Winick, “SSRL at 20 Years—Some Personal Remembrances of the Early Days,” in *Stanford Synchrotron Radiation Laboratory Users Newsletter*, Oct 1993, SLAC Archives, 2007-033 series, Box 1/3, Folder 27.

molecular physics, surface properties, biological materials and many other research areas.”⁶⁶

STRUGGLES AND ACHIEVEMENTS IN THE FIRST YEARS

The Relationship with SLAC High Energy Physicists

The ground rules for the SSRP’s operation of its facilities at SPEAR, in relation to the ordinary HEP program, were laid down in a June 6, 1973 document signed by the directors of SSRP and SLAC. The formal structure was complicated: five organizations (SLAC, AEC, NSF, Stanford University, and SSRP) plus outside user groups at SSRP were involved in a variety of contractual relationships. SLAC, operated by Stanford University as a national facility on mission from the AEC, would sit on university land property leased to the federal government through the AEC, and the buildings, utilities, and personal property at SLAC would be government property, including the SPEAR ring. Separate from this arrangement, Stanford University obtained a grant from the NSF to make use of synchrotron radiation from SPEAR, which had been approved by SLAC and the AEC. The basic premise for this auxiliary utilization of the ring was that “synchrotron radiation will be available to SSRP only during those periods when SLAC will operate SPEAR for its particle physics program,” and then be free of charge for SSRP. SLAC, for its part, “will have no scientific program responsibility for the conduct of the SSRP program”; this as well as the administrative responsibility for SSRP lay rather with Stanford University. SLAC, furthermore, had “effective control of the design and installation of the building and associated utilities, and of any hardware which connects to SPEAR, in order that SPEAR’s use for particle physics shall not be interfered with,” and “SLAC will exercise control over the SSRP facility with respect to safety, including radiation safety.” SSRP “may require certain services from time to time from SLAC, such as rigging, alignment, computation and engineering,” for which SLAC “will charge SSRP under the existing applicable rates. All costs related to construction, equipment and operations required primarily for or because of the SSRP facility will be borne directly by SSRP.” The organization of the SSRP had been developed by the university so as to be “suitable, in SLAC’s opinion, for the use of the facility at SLAC as a national resource and for maintaining a symbiotic and harmonious

66. SSRP Activity Report May 1973–Dec 1974.

relationship with SLAC.” Any changes to this organization needed to be discussed with the SLAC director beforehand, “in order that both parties reach agreement that such changes will not adversely affect the relationship of SSRP and SLAC.” Design and construction of buildings “will be accomplished by SLAC and will be charged to SSRP.” With regard to instrumentation, “SSRP understands that any hardware which is installed at the facility which connects with the SPEAR vacuum system must not affect it adversely and, therefore, that the design and the methods of fabrication, installation and operation of such hardware must be approved by SLAC.”⁶⁷

The practical meaning of all this is quite clear: SLAC high energy physicists were willing to be perfectly generous and cooperative so long as their own experiments were completely unaffected. Herman Winick had been recruited from the CEA project in August 1973 to become associate director of SSRP for technical matters and effectively the liaison between SSRP and the SLAC HEP program.⁶⁸ He remembers: “I was able to work with the high energy physicists and they were like, we’re busy, we’re doing real physics, the fact that the light doesn’t shine into your slits is your problem, you know the ground rules. And they were right.”⁶⁹

Scientific Achievements in the First Few Years

Successful experimental work was carried out nonetheless. The very first results from synchrotron radiation use at SPEAR were published in the July 19, 1974 issue of *Nature*.⁷⁰ SSRP was the only synchrotron radiation laboratory in the world to provide access to hard X-ray (down to 0.3 Ångströms) radiation, which provided the emerging user community with “unique possibilities,” as noted in a 1975 *Science* article.⁷¹ A major experimental breakthrough offered was EXAFS, a new spectroscopic method for determining the character and relative position of elements in small molecules, whose pioneers Farrel Lytle, Ed Stern, and Dale Sayers of the University of Washington traveled to SLAC and made significant developments of the technique with radiation from

67. “Statement of Operating Policies and Procedures for Operation of the Stanford Synchrotron Radiation Project Facility at SLAC,” 6 Jun 1973, SLAC Archives, Richter series 7, Box 1, Folder 2.

68. “Brief Chronological History” (ref. 35).

69. Herman Winick, interview by author, Menlo Park, CA, 10 Oct 2007.

70. Ingolf Lindau et al., “X-ray Photoemission Spectroscopy,” *Nature* 250 (1974): 214–15.

71. Arthur Robinson, “Synchrotron Radiation (I): A Light for All Seasons,” *Science* 190, no. 4219 (1975): 1074–76, on 1074.

SPEAR.⁷² Lytle describes that he was able to collect as much EXAFS data in three days at SSRP that he had managed to do in the previous ten years, and by his own account, he immediately “shut down all three X-ray spectrometers” in his home laboratory: “A new era had arrived!”⁷³ The story is not an exaggeration: the performance improvement compared to state-of-the-art home laboratory X-ray sources (rotating anode sources) at the time was an astonishing 100,000 times better intensity, meaning that the required time to take a useful EXAFS spectra was shortened by a factor of 100,000. Another EXAFS pioneer, Peter Eisenberger at Bell Labs, is reported to have bought “the most powerful rotating anode X-ray tube in the world at that time” and used it “ten days, 24 hours a day, to make a very poor EXAFS spectrum.” He took the very same experiment to SSRP and “got a much better spectrum in 20 minutes.”⁷⁴ A group around Stanford chemistry professor Keith Hodgson decided to mount a diffraction camera from their campus laboratory at the SSRP beamline to do some crystallography measurements. The results, published in 1976, benefited from radiation intensities “a factor of at least 60 greater than those obtained with a sealed X-ray tube using the same crystal and instrumental parameters.”⁷⁵ These achievements in EXAFS and crystallography initiated long-term developments in photoemission, photoelectron diffraction, and high-resolution protein structure analysis that were later viewed as particularly important for the success of hard X-rays synchrotron radiation in materials science and the life sciences.⁷⁶

Key to the success was, reportedly, the design of the original SSRP facility to maximize user access and utilization of radiation by letting several experiments share the same beamline, made possible by SPEAR’s original technical design.⁷⁷ But the most important factor for the successes that made SSRP famous in 1974 was undoubtedly the 3 GeV electron energy, unprecedented in storage rings and a prerequisite for producing synchrotron radiation in the

72. Katherine Cantwell, “20 Years of SSRL: A Semi-Personal View,” *Synchrotron Radiation News* 7, no. 2 (1994): 5–6, on 5.

73. Farrel Lytle, “The Future of XAS from a Perspective of Fifty Years,” *Synchrotron Radiation News* 20, no. 1 (2007): 9–10, on 9.

74. Herman Winick, interview by author, Menlo Park, CA, 3 Oct 2007.

75. James Phillips et al., “Applications of Synchrotron Radiation to Protein Crystallography: Preliminary Results,” *Proceedings of the National Academy of Sciences of the United States of America* 73, no. 1 (1976): 128–32, on 128.

76. SSRL Activity Report 1983.

77. “Proposal for Second Beam Line Installation and Facility Improvement (Phase I) at the Stanford Synchrotron Radiation Project,” SLAC Archives, 2009-049 series, Box 5, Folder 1.

hard X-rays regime. It had been a major reason for the NSF to choose to fund the SSRP in the first place, but unfortunately for SSRP, it soon turned out to be less treasured by the SLAC high energy physicists.

The X-Ray Drought

Among the most famous events in the history of HEP was the double discovery at BNL and SLAC of a new particle that was eventually called the J/Ψ , sparking what was later dubbed the November Revolution. The two discoveries were made independent of each other within a few weeks, and announced simultaneously. The leaders of the respective groups, Burton Richter at SLAC and Samuel Chao Chung Ting of MIT, shared the Nobel Prize in physics only two years later.⁷⁸ For the development of HEP, this was a truly decisive discovery. For SSRP, it meant a “disaster.”⁷⁹

The discovery of the J/Ψ was done with SPEAR running at 1.5 GeV per beam, which was well below its design capabilities of 3.0 GeV per beam and an energy level at which no X-rays would be produced. Following the discovery, the HEP program at SPEAR was entirely refocused to this energy region, doing further studies of the newly discovered particle and leaving SSRP with radiation only in the ultraviolet regime and a very tiny part of the soft X-ray spectrum.⁸⁰ Suddenly, three out of five experimental stations on the SSRP beamline were almost completely unusable, and the ground rules left SSRP without influence over the situation.⁸¹ In the first two years after the November Revolution in HEP, SPEAR had some occasional runs above 2.5 GeV on which SSRP could accommodate at least some of its X-ray-requesting users, but during 1977, the situation worsened, and SSRP could not even meet the requests of its highest-ranked X-ray proposals. Discussions with SLAC director Panofsky and deputy director Sidney Drell yielded the conclusion that this situation would likely continue well into 1979.⁸² In the Activity Report of July 1, 1977–March 31, 1978, newly appointed SSRP director Arthur Bienenstock wrote, together with SSRP deputy director Herman Winick under the headline “Dealing with the

78. Riordan, *Hunting* (ref. 13), 268–92; Peter Galison, *Image and Logic: A Material Culture of Microphysics* (Chicago: University of Chicago Press, 1997), 538.

79. *SSRL Users Newsletter*, Oct 1993, SLAC Archives, 2007-033 Series, Box 1/3, Folder 27.

80. Katherine Cantwell, “The Stanford Synchrotron Radiation Laboratory: 20 Years of Synchrotron Light,” SLAC-PUB-6346 SLAC/SSRL 0056, Aug 1993; Cantwell, “20 Years of SSRL” (ref. 72), 44.

81. Doniach et al., “Early Work” (ref. 59), 382.

82. Winick, “SSRL at 20 Years” (ref. 65).

TABLE 1. Synchrotron radiation runs on SPEAR, 1974–79.

	<i>User shifts</i>	<i>SPEAR shifts</i>	<i>User shifts per SPEAR shift</i>
May 12–July 2, 1974	270	150	1.80
October 6–December 15, 1974	220	125	1.76
January 19–July 14, 1975	886	324	2.73
October 18, 1975–March 31, 1976*	914	319	2.87
May 16–July 31, 1976	469	168	2.79
October 11–December 17, 1976	801	147	5.45
February 20–June 27, 1977	1442	337	4.28
November 9–December 18, 1977	396	71	5.58
January 14–July 5, 1978	1976	365	5.41
July 6–13, 1978**	204	21	9.71
October 20–December 21, 1978	604	145	4.17
January 28–March 31, 1979	614	164	3.74

* Includes seven shifts of dedicated operation during December 1975.

** One week of dedicated operation.

Source: SSRL Activity Report 1979.

X-ray Drought,” that a variety of options had been considered by both them and the NSF, including appealing to the SLAC directorate for a compromise solution, but that the basic agreement with SLAC effectively precluded any such arrangements. A renegotiation of the basic agreement with SLAC was also out of the question, and so the SSRP director and deputy director concluded that “an improvement in the situation before 1980 is unlikely to be achieved by this means.”⁸³

Meanwhile, some limited periods of dedicated time on SPEAR had been made available by SLAC, meaning runs exclusively for synchrotron radiation and with SPEAR operations determined by SSRP directors and staff. Already in November 1974, a single eight-hour shift had been provided for dedicated operation, followed by eight similar shifts in December 1975 and twenty-one in July 1978 (see Table 1). Compared to ordinary operation, dedicated runs offered not only higher energy but also several other means of adjusting operation of the machine to optimize the characteristics of the radiation.⁸⁴

83. Arthur Bienenstock and Herman Winick, “Dealing with the X-Day Drought,” Activity Report, 1 Jul 1977–31 Mar 1978.

84. Winick, “SSRL at 20 Years” (ref. 65).

By 1978, SLAC had made an agreement in principle to provide dedicated operation of SPEAR whenever possible, although not free of charge but paid for with specific grants from the NSF.⁸⁵ These shorter dedicated runs clearly did not solve the issue of the X-ray drought.⁸⁶ The long-term solution to the problem, introduced later, would be a vital part of changing synchrotron radiation forever.

A MATURING LAB

A Growing User Base

The ambition of SSRP to establish a truly national resource was propelled by the attraction of hard X-rays, but achieved by the creation of buy-in experiments, whereby external users were tied to the lab and external scientific and technical expertise was brought in, complementing that of the SSRP directors and staff. Groups of researchers from Bell Labs, California Institute of Technology, the U.S. Naval Weapons Center at China Lake, Xerox, Stanford University, and the University of Washington were contracted to build and maintain experimental stations, receiving guaranteed beamtime in return, and the geographical distribution and disciplinary breadth of these teams allegedly helped ensure SSRP's status as a broad national user facility.⁸⁷ Importantly, their involvement also meant a substantial infusion of capital, *in-kind*—the groups contributed not only with equipment designed and assembled at their home institutions but also, crucially, with their time and competence. Naturally, the monetary value of these contributions are almost impossible to estimate precisely in retrospect, but key people active at SSRP at the time speak of collected contributions from these groups at least on the level of the NSF grants; i.e., more than half of the real capital equipment and operations costs of SSRP were provided in-kind by external groups.⁸⁸

The first SSRP Users' Meeting took place on October 24–25, 1974, and attracted no less than a hundred (prospective) users.⁸⁹ The number of

85. "Stanford Synchrotron Radiation Project Organization Study," Mar 1977, SLAC Archives 2009-049 series, Box 3, Folder 4.

86. Bienenstock and Winick, "Dealing" (ref. 83).

87. Doniach et al., "Early Work" (ref. 59), 380; Doniach, interview (ref. 60).

88. Arthur Bienenstock, interview by author and Thomas Heinze, Stanford, CA, 21 Mar 2013; Ingolf Lindau, interview by author and Thomas Heinze, Menlo Park, CA, 25 Mar 2013.

89. Winick, "SSRL at 20 Years" (ref. 65).

experimenters, by which is meant the number of individuals performing experiments at SSRP over a six-month period of beam availability, grew from 4 in May 1974, to 40 in January 1975, to 120 and 200 in January 1976 and 1977, respectively.⁹⁰ Already in early 1975 there was considerable oversubscription of the beamtime available. Several new applications had also been proposed that the existing SSRP facility could not accommodate, partly due to the X-ray drought but also due to simple limits of physical capacity.⁹¹ An ambitious expansion program, calling for additional beamlines housed in a major new building, was submitted to the NSF in mid-1975, and a grant of \$741,000 ensued.⁹² In June 1976 the second beamline was taken into operation, bringing the number of experimental stations to nine and consequently increasing the number of users significantly.⁹³ In the Activity Report for April 1, 1976–December 31, 1976, the following description is found: “The intensity of activity with eight user groups, comprising thirty or so people, in the building on a continuous twenty-four-hour basis for a period of many weeks is hard to describe graphically. Suffice it to say that the building often looked like a battleground in the early morning with experimenters stretched out in all corners trying to catch a few hours sleep. The dedication of SSRP staff in a valiant attempt to help all these people was remarkable, far beyond the call of duty.”⁹⁴

In 1977, a grant of \$6.7 million was awarded the SSRP for the “Phase II” expansion, which included two new beamlines as well as a new building. Plans were also underway to make SPEAR a dedicated synchrotron radiation source on 50 percent of its running time, which would give the SSRP control over energy and other adjustable parameters. In January 30, 1976, Panofsky noted that “our problem is essentially one of embarrassment of riches in respect to both elementary particle physics and synchrotron radiation use of SPEAR” and made the promise that “when PEP has reached an operational stage at which half of PEP operating time is dedicated to HEP . . . , one-half of SPEAR’s operating time can be dedicated to synchrotron radiation running.” This promise, writes

90. “Organization Study” (ref. 85).

91. Sebastian Doniach, William Spicer, and Herman Winick, “Proposal for Second Beam Line Installation and Facility Improvement (Phase I) at the Stanford Synchrotron Radiation Project,” n.d., SLAC Archives, 2009-049 series, Box 5, Folder 1.

92. Winick, “SSRL at 20 Years” (ref. 65); Doniach et al., “Early Work” (ref. 59), 381.

93. Sebastian Doniach and Herman Winick, “Proposal to the National Science Foundation for Developmental Funds for the 1976–77 Year at the Stanford Synchrotron Radiation Project,” Dec 1976, SLAC Archives 2009-049 series, Box 4, Folder 55.

94. SSRL Activity Report, 1 Apr–31 Dec 1976.

Herman Winick, was necessary to give weight to the SSRP Phase II proposal. (Fifty percent dedicated time began in fiscal year 1979; see below.)⁹⁵

In May 1976 the SSRP proposed to the NSF a “change in philosophy” with regard to its operation, which meant the appointment of an in-house scientific staff to help users and work on facility development, as part of making the lab into an NSF-funded “National Synchrotron Radiation Center.” The original charter given to SSRP in January 1973 was that it should be a “minimum facility,” designed to “test out the concept of using a high-energy multi GeV storage ring for synchrotron radiation research.” Since then, the application states, “this mandate has continued to dominate the philosophy under which SSRP has been funded,” with staff kept to a minimum and scientific personnel associated with SSRP left to find funding for their own research at SSRP externally (see Table 2). The scientific successes and the growth in user numbers had been matched by 1975 and 1976 funding increases that enabled an appropriate expansion on the technical side, but no similar funding increase to expand the support staff and scientific staff. The proposal, therefore, was that the “minimum facility” philosophy be substituted for a more generous charter, enabling SSRP to build a scientific staff with “responsibility for helping users with their research, for facility development, and for maintaining their own expertise by performing their own research programs.”⁹⁶

A New Organization and a New Name

In 1976 the National Academy of Sciences (NAS) issued an “assessment of the current status of synchrotron radiation facilities in the U.S. and the demand for beamtime among U.S. scientists,” which concluded that future needs would soon surpass the capabilities of existing facilities. The panel recommended a major expansion, and in very short order the Energy Research and Development Administration (ERDA, the successor to the AEC and the predecessor of the DOE) and the NSF started funding new facilities. ERDA funded the 0.75 and 2.5 GeV National Synchrotron Light Source (NSLS) rings at BNL.⁹⁷

95. Panofsky is quoted in Winick, “SSRL at 20 Years” (ref. 65).

96. Sebastian Doniach et al., “Renewal Proposal to the National Science Foundation for Operating and Research Costs for the Stanford Synchrotron Radiation Project, Period: 1 November 1976–October 31, 1977, Amount Requested: \$937,724,” May 1976, SLAC Archives, 2009-049 series, Box 5, Folder 8.

97. Robert Crease, “The National Synchrotron Light Source, Part I: Bright Idea,” *PiP* 10 (2008): 438–67; Robert Crease, “The National Synchrotron Light Source, Part II: The Bakeout,” *PiP* 11 (2009): 15–45.

TABLE 2. Funding from the NSF, 1972–77.

	Amount	Period	Purpose
GH-36836	\$59,000	January 1–June 5, 1973	Pilot Project
DMR73-07692	\$750,000	June 6, 1973–April 14, 1974	Development and Operation
Amendment 1	\$450,000	April 4–October 31, 1974	Development and Operation
Amendment 2	\$400,000	November 1, 1974–October 31, 1975	Operation
Amendment 3	\$75,000	November 1, 1974–October 31, 1975	Operation Supplement
Amendment 4	\$300,000	June 1, 1975–December 31, 1975	Beam Line II, Phase I
Amendment 5	\$531,000	November 1, 1975–October 31, 1976	Operation
Amendment 6	\$406,000	January 1–December 31, 1976	Beam Line II, Phase II
Amendment 7	\$43,600	January 1–December 31, 1976	Dedicated SPEAR Time
Amendment 8	\$25,000	June 1–December 31, 1976	Operation Supplement
Amendment 9	\$35,000	August 1–October 31, 1976	Beam Line II Supplement
Renewal Proposal	\$800,000	November 1, 1976–October 31, 1977	Operation and Beam Line III, Phase I

Source: “Organization Study” (ref. 85).

The NSF funded the \$6.7 million “Phase II” expansion at SSRP and a new 0.8 GeV ring (named “Aladdin”) at the University of Wisconsin to replace Tantalus.⁹⁸ The NAS review also actualized the need to take the synchrotron radiation activities at SLAC into a new organizational form, and the NSF put in place an “organization study” of SSRP, with the goal to make a recommendation of a new SSRP organizational structure to be implemented with the “Phase II” expansion program.⁹⁹

The organization study saw three principal possibilities for a new SSRP organization: a “stand-alone research facility within Stanford University” directly under its vice provost for research; a division of SLAC with an associate director of SLAC for SSRP; and a new entity under Stanford and the LBL/University of California jointly. The two latter were dismissed by the study as

98. Winick, “SSRL at 20 Years” (ref. 65).

99. “Organization Study” (ref. 85).

“not viable,” the Stanford/LBL alternative because the sponsoring agency for LBL, the ERDA, was already proceeding with the construction of a dedicated synchrotron radiation facility at BNL (while the NSF was sponsoring the expansion of SSRP), and the joint SSRP/SLAC alternative because “the mixing of a multi-discipline lab with a relatively small budget with a very large single discipline lab would be extremely difficult.” The study thus recommended the first alternative, and as a result, on October 27, 1977, the “project” SSRP was turned into an independent laboratory within Stanford University under the vice provost for research, renamed the Stanford Synchrotron Radiation Laboratory (SSRL).¹⁰⁰

A renegotiation of the SSRL-SLAC Memorandum of Understanding (MoU) ensued, resulting in a new document reiterating the ground rule that SSRL use synchrotron radiation from SPEAR on a “non-interference” basis, but also stating the ambition that “dedicated time” for synchrotron radiation at SPEAR would be provided by SLAC “in any period in which SPEAR will not be operated for its particle physics programs,” with a fee charged per shift, “calculated to reimburse SLAC for the full costs of such operation.” In its other parts, including the scientific responsibility for the SSRL program, the installation of hardware on SPEAR, the use of SLAC services, and the procedures for allocation of experimental time at SSRL to outside users, the new MoU repeated what had been laid down in the agreement from June 6, 1973, as cited above.¹⁰¹

The Wiggler

But the X-ray drought was still a very palpable problem that urged a long-term solution.

In the mid-1970s the production of synchrotron radiation in storage rings (and synchrotrons) was typically achieved by using the so-called “bending magnets” found in the curved sections of the rings, which force the electrons to make a turn whereby they emit radiation in a broad planar angle. But significantly more efficient and controllable ways of producing the radiation had been discussed already in the 1960s (and were mentioned in the 1972 Fischer study), namely the insertion of arrays of magnets in the straight

100. Ibid.; *SSRL Users Newsletter*, Oct 1993 (ref. 79).

101. “Memorandum of Understanding Concerning Operation of the Stanford Synchrotron Radiation Laboratory (SSRL) at the Stanford Linear Accelerator Center (SLAC),” 1 Oct 1977, SLAC Archives, Panofsky series IV, subseries F, Box 50, Folder 2.

sections of accelerators, so-called “insertion devices,” that make the electrons turn several times and thus emit radiation several times more intense.¹⁰² By the mid-1970s the concept had matured to the stage that several synchrotron radiation laboratories worldwide started planning for the implementation of insertion devices of the “wiggler” type, with electromagnets. At SSRP, calculations showed that a wiggler could solve the problem of the X-ray drought by producing hard X-rays also at lower beam energies.¹⁰³

Some fifteen years later, Herman Winick, one of SSRP’s champions of the wiggler concept, recalled the risks involved, noting that “there had been mixed experience with wiggler magnets” and furthermore that as parasites, SSRP “would not be able to turn on the wiggler . . . if it caused problems with the high energy physics program.” At a wiggler workshop at SLAC in March 1977, “67 accelerator experts from around the world” unanimously concluded that their preferred course of action was a “conservative plan to build and install the wiggler, but not commit to the experimental stations until it was proven to be compatible with the operation of the ring.” When SPEAR started up in October 1978 after a regular maintenance shutdown, the newly installed wiggler could be turned on, and its impact on SPEAR operation assessed. Interestingly, the installation not only proved compatible with the regular operation of SPEAR, but also directly beneficial to the HEP program, enlarging the transverse beam size and thus allowing a higher current. Wrote Winick, “although this effect was anticipated, it caused much excitement when it was observed to be real and somewhat larger than expected.”¹⁰⁴

For the synchrotron radiation experiments, the effect was even more rewarding: The wiggler enabled SPEAR, running at 2 GeV, to produce radiation of the same quality and wavelength (X-rays) as it had previously done at 3 GeV, through bending magnets.¹⁰⁵ The wiggler, thus “meeting all expectations,” led to the immediate revision of the Phase II extension plans and “a tough decision” by the new SSRL director Bienenstock to trade two planned bending magnet beamlines, one of which was already under construction, for a second wiggler, as part of the major expansion program executed in 1978–80 (see below). “Thus the era of insertion devices started,” wrote Herman Winick some fifteen years later. In 1978–80, an SSRL/LBL collaboration produced the

102. Fischer, “Study” (ref. 53), 30–31.

103. Winick, interview (ref. 69).

104. Winick, “SSRL at 20 Years” (ref. 65).

105. Herman Winick, “The Wiggler Magnet Is a Success,” *SSRL Users Newsletter*, Mar 1979, SLAC Archives 1999-001 series, Box 1/2, Folder 28.

first permanent magnet insertion devices, called undulators, that complemented and partly superseded wigglers in performance. These undulators, inserted into SPEAR in the early 1980s, were “a primary impetus to the proposals for the third generation sources, such as the Advanced Light Source (ALS) [at LBL, starting operation in 1993], and the Advanced Photon Source (APS) [at ANL, starting operation in 1996], as well as similar facilities around the world, all built with undulators as the main source of radiation.”¹⁰⁶

According to the SSRL director at the time, Arthur Bienenstock, the willingness of the NSF to show support and commit funds to the wiggler project was decisive for its success, as was the assistance of the SLAC staff who provided a lot of technical support.¹⁰⁷ Generally, it would seem, the willingness of the NSF to endorse and monetarily support quite bold initiatives on behalf of the SSRP/SSRL leadership is part of the explanation for the relative success of the lab in its first decades, in spite of the suboptimal technical (and organizational) circumstances described above and below.¹⁰⁸

Expansion and Part-Time Dedication

In March 1978 SSRL had eleven simultaneously operating experimental stations; six on beamline I (two ultraviolet and soft X-ray, four X-ray), four on beamline II (all X-ray), and one station on a newly installed third beamline. But user demand continued to increase, and in the spring of 1978 the laboratory began its three-year, \$6.7 million facilities expansion program, aimed at getting seven new beamlines with about fourteen experimental stations on the south arc of SPEAR operational in 1980, when SPEAR was expected to be available for use as a dedicated synchrotron radiation source for at least 50 percent of its operation time.¹⁰⁹

The dedication ceremony for the \$6.7 million expansion program was held on October 27, 1977, simultaneously with the organizational change and name change to SSRL, and in connection with the 1977 users meeting that attracted over 160 researchers from six countries.¹¹⁰ The expansion was executed in two phases, the first one readying four beamlines and a building to host them, and

106. Winick, “SSRL at 20 Years” (ref. 65).

107. SSRL Activity Report, 1 Oct 1978–31 Mar 1979.

108. Bienenstock, interview (ref. 88); Lindau, interview (ref. 88).

109. SSRL Activity Report, 1 Jul 1977–31 Mar 1978.

110. “SSRL Dedicates Expansion Program,” *SSRL Users Newsletter*, Dec 1977, SLAC Archives, 1999-001 series, Box 1/2, Folder 28.

the second one adding three new beamlines and a building extension. The approval of the expansion plans was preceded by a site visit team consisting of external experts as well as NSF staff on March 24–25, 1977, charged with the task of reviewing not only the expansion plans but also “how they relate to existing and planned facilities elsewhere in the U.S.” Specifically, the reviewers were instructed to take into account “the constraints imposed on the SSRP expansion by the SLAC schedule for high energy experiments” and propose how these constraints could be solved. Acknowledging that beamlines I and II of SSRP would be the only U.S. sources of synchrotron radiation in the X-ray range open to external users for several more years, the site visit team instructed the SSRP to prioritize hard X-rays and leave the other wavelength region to the SRC in Wisconsin. It also concluded that the SSRP was “understaffed with respect to serving users,” and that in order to manage the expansion, it would have to hire several new scientists, engineers, and administrators.¹¹¹

In June 1977 SLAC had begun constructing its next big HEP machine, the PEP (Positron-Electron Project), a larger storage ring for particle collisions (1.4 miles or 2.2 km in circumference, compared to SPEAR’s 234 m), and its completion would mean that SPEAR ceased to be the flagship HEP facility of SLAC, which enabled Panofsky to promise to make SPEAR available for dedicated synchrotron radiation operation for 50 percent of its running time.¹¹² On October 1, 1979, “earlier than the date tied to PEP operations for physics,” Panofsky’s promise was effectuated, and SPEAR was committed to dedicated synchrotron radiation production for 50 percent of its operating time.¹¹³ SPEAR operation was now a matter for joint planning by SSRL and the SLAC HEP division, but SLAC was still in charge of the linac that provided SPEAR with electrons, and was about to start using it also for PEP injections.¹¹⁴ The relationship was still, at least partly, parasitic.

Although it is fair to say that, considering the means at its disposal, SSRP/SSRL performed very well scientifically in its first five years as a user facility, the prospects of significantly enhanced scientific performance must have looked remarkably good in 1980: the wiggler had relieved the lab of the

111. “Stanford Synchrotron Radiation Project Site Visit Report,” 25 Mar 1977, SLAC Archives, 2009-049 series, Box 3, Folder 2.

112. Doniach et al., “Renewal Proposal” (ref. 96).

113. Cantwell, “20 Years of SSRL” (ref. 72); Arthur Bienenstock and Wolfgang Panofsky, “The Use of SPEAR Jointly by SLAC/HEP and SSRL Beginning October 1, 1979,” SLAC Archives, Panofsky series IV, Box 51, Folder 1.

114. Bienenstock and Panofsky, “Use of SPEAR” (ref. 113).

X-ray drought, and 50 percent of the running time on SPEAR was now dedicated to synchrotron radiation, meaning that SSRL was in charge of energy, current, and other factors for quality and stability of the synchrotron radiation. In 1980 SSRL director Bienenstock consequently remarked that “group after group” left their experimental sessions at the lab “indicating that they finally got the data they had sought.” But nonetheless, wrote Bienenstock, the weaknesses of the lab were also becoming more evident, not least the strain on the staff charged with operating no less than eleven experimental stations while also being involved in the construction of several more.¹¹⁵

Consolidation after the Expansion

The 1980–81 SSRL Activity Report described a time of “major transition for SSRL from primary emphasis on the three-year construction program to concentration on user support.” It reported on significantly improved user services due to reorganization and reallocation of personnel, but also continued over-subscription of time and user support due to further growth in user numbers.¹¹⁶ But the lab had also consolidated its status as a user facility; the text of the February 1980 *Proposal Guidelines Information Booklet* described a lab with routinized operation, user handling and experiment support, two calls for proposals each year, differentiation between proposals for single experiments and longer-term experimental programs, a well-established system of proposal review panels, and scheduling procedures based on the requests of the users and technical capabilities of the machine, all of which are features typical for recent and contemporary (1990s and 2000s) synchrotron radiation facilities.¹¹⁷

An NSF “ad-hoc site visit committee,” touring SSRL on June 18 and 19, 1979, had noted the impressive expansion from pilot project in 1973 to broad national user facility in 1979, especially mentioning the wiggler and the several new beamlines and experimental stations, some of which provided opportunities “which [have] not been available at any synchrotron radiation source,” and concluded that the facility was “a unique and important national resource” and “certainly one of the world’s leading synchrotron radiation centers.” The committee thus stated that “this is a time to begin the consolidation of the gains at SSRL,” by work to “optimize the utilization of the remarkable

115. SSRL Activity Report, 1 Apr 1979–31 Mar 1980.

116. SSRL Activity Report, 1 Apr 1980–31 Mar 1981.

117. “Stanford Synchrotron Radiation Laboratory Proposal Guidelines and General Information,” Feb 1980, SLAC Archives, 2007-033 series, Box 1/3, Folder 12.

experimental tools which have just been built.” Assessing the views of the SSRL users, the committee noted that many users “have complimented the SSRL staff for the service they have provided, but at the same time have also complained about the lack of various items of instrumentation, the lack of enough staff to help users, and at the need for proper characterization of the SSRL instruments,” limitations that “are due in part to the rapid growth in usage and in part to the limited funds which have been available.” Not surprisingly, the committee recommended an increase of the operating funds but also demanded clarifications of the responsibilities of staff “in terms of the SSRL mission.”¹¹⁸

The efforts to transition into more normal operations after the hectic expansion appeared to have been successful; the 1981–82 Activity Report stated that it was “difficult to summarize SSRL activity during the past year without frequent use of superlatives.” Not least, said the report, there had been “a dramatic increase in experimental capability at SSRL” including the ability of researchers to “more effectively pursue increasingly complex experiments with a high level of confidence in the SPEAR beam and SSRL facility equipment.” The impressive scientific performances were “a testimonial to the skill and hard work of the SSRL staff and our SLAC colleagues responsible for the operation and improvement of SPEAR.”¹¹⁹

The Move to the DOE

The demands for organizational renewal of SSRL after its quite dramatic growth and expansion in the second half of the 1970s and the early 1980s culminated with the 1978–80 expansion program and the 1979 dedication of 50 percent of SPEAR running time to synchrotron radiation. In the early 1980s, the NSF’s responsibilities for SSRL had grown from supporting a comparably small-scale university-level (yet national in scope) synchrotron radiation project to overseeing a large lab with partial responsibility for a major piece of accelerator infrastructure, something not very typical for the foundation. Such responsibilities usually lay with the newly created DOE, the successor of the AEC and ERDA, who had its own synchrotron radiation installation at BNL, the NSLS, which opened to users in 1982, and was engaging in plans to build at least one additional such facility within its system of national labs.

118. “Report of a SSRL Site Visit, Stanford University, September 22, 23, 1980,” SLAC Archives, 2009-049 series, Box 3, Folder 2.

119. SSRL Activity Report, 1 Apr 1981–31 Mar 1982.

Against this background, the decision had been made at the SSRP already in 1976 to submit the proposal for the \$6.7 million expansion program not only to the NSF but also to the ERDA. At that time it was decided that the responsibility for the SSRP should remain with the NSF, mainly because the ERDA was to focus its efforts on the NLSL, but there was an inescapable logic to the idea of moving SSRP/SSRL over to the ERDA/DOE.¹²⁰ As SSRL continued to grow, it was soon “beyond the scope of a traditional NSF project” and in terms of performance and numbers on users well on par with the DOE flagship synchrotron radiation facility, the NLSL.¹²¹ The DOE, having identified synchrotron radiation as a national scientific resource demanding the operation of large accelerator facilities, was better equipped to fund and oversee this growing experimental resource than the NSF, and also saw the “appropriateness of having the two major national synchrotron radiation laboratories, NLSL and SSRL, under one agency so that the complimentary [*sic*] growths could be planned carefully.” Moreover, there were some fears among the NSF’s National Science Board that long-term commitments to funding large facilities would harm the fulfillment of its “basic goal of funding individual American scientists.”¹²²

On October 1, 1982, responsibility for the SSRL was transferred from the NSF to the DOE. As stated in the 1983 SSRL Activity Report, the lab was thereby placed under the oversight of an agency “quite experienced and accomplished in the support of national facilities.” The initial fear among SSRL staff that the DOE would treat the lab as a stepchild and let the success of the NLSL come at its expense were proven wrong when the DOE showed its financial muscles and increased the budgets for operating, maintaining, and developing physical infrastructure at SSRL as well as the sustaining and development of a vivid in-house research program.¹²³

STRUGGLES AND ACHIEVEMENTS IN THE 1980S

Limits to Growth?

The move of SSRL from the NSF to the DOE necessitated a new MoU between SSRL and SLAC, signed on the eve of the transition, September

120. “SSRL Expansion Program: Review of Historical Developments,” 11 Sep 1980, SLAC Archives, 2009-049 series, Box 3, Folder 2.

121. Cantwell, “20 Years of SSRL” (ref. 72).

122. SSRL Activity Report 1983.

123. *Ibid.*

30, 1982, by Panofsky, Bienenstock, Gerald Lieberman (Stanford University Vice Provost and Dean of Graduate Studies and Research), and Edward Cilley (Director of the Stanford University Sponsored Projects Office). The new MoU largely reiterated the principles of earlier MoUs (as cited above), most importantly of course noting that “SLAC will have no scientific program responsibility for the SSRL program” but will assist the SSRL in the installation and maintenance of equipment on the SPEAR accelerator facility “limited only by the proviso that such accomplishment does not, in the judgment of the SLAC Director, adversely affect the SLAC primary mission which is research in high energy physics” and by the basic principle that “SLAC must have effective control of the design and installation of the SSRL buildings and associated utilities.”¹²⁴ In other words, not much changed. In principle, the SSRL had 50 percent of the running time of SPEAR dedicated to its scientific program, but SPEAR was still owned by SLAC and connected to the SLAC linac for injections; furthermore, SLAC was indisputably a single-purpose, single-mission national lab for HEP.

Thus when the DOE continued its efforts to strengthen and develop synchrotron radiation nationally, SSRL was stuck in its parasitic mode and the limits to expansion that it set. In 1982, it was revealed that the LBL, determined to find a new mission after its last accelerator facility for HEP had been closed, planned the development of a specialized ultraviolet synchrotron radiation source.¹²⁵ In a kind of Bay Area division of market shares, an agreement was made between lab directors that SSRL would focus on strengthening its activities in the hard X-ray range, so that the two labs could become complementary pieces of a national stronghold for synchrotron radiation, also collaborating on certain vital technological developments such as insertion devices (see above). In SSRL’s view, this arrangement called for further expansion of instruments at SPEAR and on the new PEP ring (see below), and perhaps even the construction of an entirely new accelerator on the SLAC site. But these visions were not shared by Panofsky, who “made it absolutely clear to Bienenstock . . . that any such activities can not take any priority on SLAC resources, and that the execution had to be compatible with the high energy physics commitments of SLAC.” In Panofsky’s view, the SSRL used as its primary infrastructure

124. “Memorandum of Understanding Concerning Operation of the Stanford Synchrotron Radiation Laboratory (SSRL) at the Stanford Linear Accelerator Center (SLAC),” 30 Sep 1982, SLAC Archives, Panofsky series IV, Box 51, Folder 1.

125. Catherine Westfall, “Retooling for the Future: Launching the Advanced Light Source at Lawrence’s Laboratory, 1980–1986,” *HSNS* 38, no. 4 (2008): 569–609.

“a storage ring they did not build and for which they have no operational responsibility,” and SLAC “has no obligation to support SSRL except on the basis of priority second to that of the high energy physics program.” This arrangement “simply could not work” if SSRL proposed to build a new ring on the SLAC site, optimized for X-rays synchrotron radiation, and so any plans to build such a new facility would demand a reevaluation of the organizational framework in which the SSRL and SLAC coexisted.¹²⁶

Clearly, the new SSRL plans actualized the question of the long-term status of SSRL at SLAC. In late November 1982 the expansion project reached the stage of a proposal to the DOE, worth \$9 million and including both performance enhancements of the SPEAR ring, new insertion devices and beamlines on both SPEAR and PEP, and associated experimental equipment.¹²⁷ An additional “level II” expansion program was reportedly also under planning, not included in the proposal and without specifications but estimated to cost \$18 million.¹²⁸ Panofsky had doubts over the viability of the ambitious expansion program suggested by SSRL, citing what he thought were overoptimistic budgets and inappropriate manpower to carry it out, and concluded that SLAC would not lend its support to a proposal to the DOE for an expansion program going beyond the proposed level I, and especially not future construction of a dedicated storage ring.¹²⁹ Richter concurred, citing legitimate worries “about the budget and schedule,” and most importantly, arguing that the \$18 million plan was large enough to require a “fundamental reexamination of the relation between SSRL and SLAC.” Richter noted that after these considered opinions of his and Panofsky’s had been communicated with SSRL, “Bienenstock agreed to submit the smaller scope project and to drop the larger scope project for the present.”¹³⁰ But it seems Pandora’s box had been opened.

What essentially followed was an almost decade-long continuous discussion among SLAC directors and faculty, SSRL directors and faculty, Stanford University presidents and provosts, and DOE officials over the status of SSRL

126. Wolfgang Panofsky, memo, 18 Nov 1982, SLAC Archives, Richter series 7, Box 4, Folder 1.

127. “Cost Estimation of SSRL Construction Projects Level I (Total Cost \$9.0M),” 22 Nov 1982, SLAC Archives, Richter series 7, Box 7, Folder 7.

128. Burton Richter, memo to files, 29 Nov 1982, SLAC Archives, Richter series 7, Box 7, Folder 7.

129. Wolfgang Panofsky, memo to files, 24 Nov 1982, SLAC Archives, Richter series 7, Box 7, Folder 7.

130. Richter, memo, 29 Nov 1982 (ref. 128).

at SLAC and the possibilities and risks of diversifying the mission of SLAC to include SSRL as a division of the lab. The issues were many. Most of all, the crucial differences between the two organizations were repeatedly pointed out: While the SSRL was a scientific user organization with a successful scientific record and a larger numbers of outside users than that of SLAC, it depended heavily on SLAC for technical operations and not least on the provision of the basic physical infrastructure for its operations, the SPEAR ring. SLAC, a single-purpose laboratory run according to the GOCO (Government Owned, Contractor Operated) principle, had a comparably simple management structure and stewardship relationship with the federal government, administered by a single office within the DOE. By virtue of this agreement with federal authorities, the directors of SLAC were indeed required to pay undivided attention to HEP—any support to the SSRL should always come second. SLAC considered its single-mission status a true strength, and should this be changed, argued Panofsky, “this would result in considerable cost in terms of SLAC’s simplicity of management and single-minded dedication to its high energy physics mission.”¹³¹ In an “all hands memo” in August 1983, Panofsky elaborates:

A frequently advanced reason for abandoning the single-function role of SLAC derives from the expected finite lifetime of SLAC’s high energy physics tools, that is, the accelerator and colliders. . . . The argument based on the potential obsolescence of SLAC’s facilities as a reason for abandoning its single-function status is at best premature. We all know that the single-function status of SLAC has served the laboratory, the university and the physics community well. SLAC (and Fermilab) have avoided the recurring identity crises besetting all multi-function laboratories. To a significant extent the multi-function laboratories have become “job shops” competing with university research. Under a multi-function regime there is no focus of responsibility within the government agencies for the health of the laboratory. Thus, while a transition to multi-function status may become necessary in the future for a number of reasons, such a decision should only be reached with full realization as to its cost.¹³²

These statements appeared for the most part to have discouraged SSRL director Bienenstock in his ambitions to expand SSRL further within the framework of a deepened collaboration with SLAC, which seemed largely

131. Wolfgang Panofsky, memo to Dr. Albert Hastorf, Provost of Stanford, 9 Dec 1982, SLAC Archives, Richter series 7, Box 7, Folder 9.

132. Wolfgang Panofsky, memo to all SLAC faculty, 22 Aug 1983, SLAC Archives, Richter series 7, Box 4, Folder 1.

uninterested in such a collaborative effort. In 1983, there were signs that SSRL instead had started to make plans “on how they could go it alone in the future.”¹³³ It was soon realized, however, that such an independent SSRL pursuit would be highly inefficient; as noted by an ad hoc committee on the organization of SSRL put together by Stanford Provost Hastorf in June 1983, “the ability of SSRL to have call on a range of SLAC resources has been crucial to its success during the period of explosive growth in the synchrotron radiation field in the last years.” Noting the strong aversion of SLAC to leave its single-mission, single-purpose status behind, and concluding that the SSRL expansion plans were essentially impossible for SSRL to undertake completely on its own, the committee suggested that a status quo be preserved in the SSRL-SLAC relations, but it also acknowledged that not much was certain regarding the long-term future of the two labs and what this would mean for their eventual organizational relationship.¹³⁴

Big Plans

In a February 1983 *SSRL Users Newsletter*, director Bienenstock wrote that “[i]n spite of all our expectations for a relatively simple 1982, the year has turned out to be one of the most administratively demanding in the laboratory’s existence.” In this regard, wrote Bienenstock, the transfer from the NSF to the DOE was complemented by the discussions over SSRL-SLAC relationships, the joint proposal with LBL to expand the X-rays capabilities at SPEAR as a complement to LBL’s proposed ultraviolet synchrotron radiation source, and not least the decision to propose a new, all wiggler/undulator, dedicated synchrotron radiation source on the SLAC site.¹³⁵ The latter point was elaborated on in the 1983 Activity Report, where Bienenstock wrote that “our goals for the future are not limited by SPEAR and PEP. A New Ring Study Group has been functioning actively to develop a conceptual design for a next generation, dual storage ring system dedicated to synchrotron radiation production. These rings are being designed to bring out the full capabilities of wigglers and undulators as synchrotron radiation sources.”¹³⁶

133. Richter, memo to files, 18 Jul 1983, SLAC Archives, Richter series 7, Box 7, Folder 9.

134. “Report of the Ad Hoc Committee on Organization of SSRL,” 1 Jun 1983, SLAC Archives, Richter series 7, Box 6, Folder 5.

135. Arthur Bienenstock, “Future Plans for SSRL: A Report from the Director,” *SSRL Users Newsletter*, Feb 1983, SLAC Archives, 1999-001 series, Box 1/2, Folder 28.

136. SSRL Activity Report 1983.

The plans for this major new facility project cohered with new opportunities opening at the federal level. The growing national demand for high-quality synchrotron radiation had led to a host of different facility plans being drafted in the late 1970s and early 1980s, among them a large, all-insertion device machine operating at energies between 5 and 8 GeV.¹³⁷ In order to prevent “other labs to get ahead of SSRL in a cue [*sic*] for new projects,” the SSRL decided to move fast on the design of a new source of this type with the ambition to include it as a construction project already in the FY86 federal budget requests. The project was estimated at \$100–150 million.¹³⁸ But other things got in the way, including the high-level politics that eventually placed the 7 GeV radiation source at ANL, the internal SSRL-SLAC politics that prevented any major construction project from competing with the large SLAC Linear Collider (SLC) (see below), and the exploitation of PEP as a synchrotron radiation source.¹³⁹

Already the Activity Report for April 1, 1980–March 31, 1981, mentioned plans to mount an undulator beam line on PEP for synchrotron radiation. PEP, not yet in operation but clearly the new HEP flagship on the SLAC site, was expected to produce synchrotron radiation with “several orders of magnitude increases in brightness,” and the efforts to get access to this potentially extraordinary radiation were intensified in 1981 and 1982.¹⁴⁰ In July 1983 Richter recommended to Panofsky to approve the PEP beamline project as suggested, and by the end of 1984, conventional construction of the synchrotron radiation facility at PEP was completed.¹⁴¹ The SSRL Activity Report for 1985 noted that “even when PEP is operated in a mode parasitic to high energy physics,” the radiation produced “will make possible a variety of experiments which cannot be performed otherwise.”¹⁴² The first real operation of the PEP beamline was conducted in 1986 and confirmed the expectations, and in October 1987 a workshop on PEP as a synchrotron radiation source was attended by 125 scientists from laboratories in the United States, Europe and

137. Westfall, “Institutional Persistence” (ref. 8).

138. Richter, memo, 18 Jul 1983 (ref. 133).

139. Westfall, “Institutional Persistence” (ref. 8).

140. SSRL Activity Report, 1 Apr 1980–31 Mar 1981; SSRL Activity Report, 1 Apr 1981–31 Mar 1982.

141. Burton Richter to Wolfgang Panofsky, 11 Jul 1983, SLAC Archives, Richter series 7, Box 4, Folder 14; SSRL Activity Report 1985.

142. SSRL Activity Report for 1985. (Note: The Activity Report 1985, ref. 141, concerns the year 1984. The Activity Report for 1985, this ref., concerns the year 1985.)

Japan, showing great interest in the “unique” performance parameters of PEP. Expectations held that PEP would make possible experiments that otherwise would have to be postponed “until the mid 1990s when new, third generation rings designed for these performance levels are expected to start operation” and also “serve as a test bed for these new rings and for the development of their insertion devices and beam line instrumentation.”¹⁴³ In all, these events and the expectations they bred caused SSRL to conclude that their future laid rather in SPEAR and PEP than in competing for an all-new ring project.¹⁴⁴

A Second X-Ray Drought

Meanwhile, the improvement of SPEAR and the expansion of its use continued. In the summer of 1984, the procedure for injecting electrons into SPEAR was modified so that the machine operation became somewhat less dependent on a well-functioning SLAC linac, which increased the amount of dedicated time for synchrotron radiation and reduced its cost to SSRL. Later the same year, the first undulator beamline at SPEAR was put into operation.¹⁴⁵

But SLAC remained a leading U.S. HEP lab, together with Fermilab, and continued to develop its accelerator-based hunt for elementary particles. The PEP project had been jointly run with LBL, and was a giant colliding beams storage ring, essentially a SPEAR many times larger and with several times higher energies. But PEP never produced the spectacular results that had been expected, and it clearly did not deliver on par with SPEAR and the November Revolution. Instead, the physics done at PEP pointed out a next step for SLAC by hinting at opportunities in a much higher energy region, which would require a linear collider to explore. Burton Richter’s bold idea to let two bunches of accelerated particles from the SLAC linac deviate into separate tunnels and then collide head-on was soon turned into the SLAC Linear Collider (SLC) concept, and construction started in 1983.¹⁴⁶ Quite expectedly, the gargantuan PEP and SLC projects dominated SLAC operations and placed heavy demands on the whole laboratory organization for most of the 1980s. Thus while the HEP program on SPEAR never infringed on the 50/50 share agreement with SSRL, the dedicated operation of SPEAR for synchrotron

143. SSRL Activity Report 1987.

144. “Report on Workshop on PEP as a Synchrotron Radiation Source, October 20–21, 1987,” SLAC Archives, 1998-001 series, Box 1/3, Folder I.

145. SSRL Activity Report 1985.

146. Panofsky, *Panofsky* (ref. 13), 138–40.

TABLE 3. Annual percentage of scheduled dedicated time on SPEAR for synchrotron radiation actually delivered to users, 1979–89.

Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
%	78.2	64.9	72.7	79.8	78.9	80.7	66.1	70.9	69.2	0.0	43.4

Source: SSRL Activity Report 1989.

radiation was still incident to SLAC operations and not least the linac, which injected electrons and positrons into PEP throughout the 1980s and, furthermore, from 1983 was partly rebuilt into the SLC. As shown in Table 3, the ten years following the 1979 dedication of 50 percent of SPEAR running time to synchrotron radiation saw heavy fluctuations in the amount of time actually delivered. In 1988, at the height of SLC construction, there was no dedicated operation at all. Also synchrotron radiation operations on PEP suffered during this time: In the years 1986 to 1989, SLAC's heavy prioritization of SLC over all else caused the cancellation of several scheduled PEP runs for HEP, to the dismay of SSRL whose parasitic runs on PEP had been quite promising.¹⁴⁷ SLAC's status as a single-purpose HEP lab, and SSRL's status as parasites, were seldom more explicitly demonstrated. A 1989 DOE report on the performance of the NSLS and the SSRL pointed out shortcomings of operation stability and user friendliness at both labs, and in the case of SSRL referred to the main problem as an "X-ray drought" caused by "poor maintenance of SPEAR in the absence of HEP interest" and "limited availability of the linac."¹⁴⁸

But the SSRL nonetheless performed quite well, considering all these troubles, and continued to expand and make technical improvements. In 1985, two new undulator beamlines were completed at SPEAR, providing "extremely brilliant radiation" in the soft X-ray range.¹⁴⁹ The continuing expansion allowed the accommodation of a steadily growing number of users, and in 1987, during which no less than five new experimental stations were put into operation, SPEAR reached an all-time high of 4,190 delivered user-shifts. In December of 1987 PEP reached a level of performance that made it "by far the highest brightness synchrotron radiation source in the world." A comprehensive "SSRL enhancement project" was also completed in 1987, comprising

147. SSRL Activity Report 1986.

148. "Synchrotron Facilities Supported by the Department of Energy: A Final Report Submitted to the DOE Council on Materials Science," 11 Jan 1989, SLAC Archives, Richter series 7, Box 8, Folder 5, on 20.

149. SSRL Activity Report for 1985.

a number of smaller improvements to various parts of the SPEAR ring that provided SSRL users with several incremental performance increases, as well as a new building with support facilities such as machine shops, vacuum clean rooms, electronics shops, a biotechnology laboratory, a central computer facility and staff offices, conference rooms, and a library.¹⁵⁰

Thus while the second X-ray drought continued, SSRL was making strong and quite successful efforts to enhance its scientific program and user support. Consequently, the 1988 Activity Report described 1988 as “a year of stark contrasts.” Unquestionable scientific successes on PEP were paired with the delivery of zero shifts of dedicated synchrotron radiation operation on SPEAR (see Table 3).¹⁵¹ SSRL users were described as having developed a “love-hate relationship” with the lab, repeatedly returning to use its “unique facilities” but simultaneously condemning the poor reliability and the unpredictability of beamtime access.¹⁵²

In 1989 the SLC began operation, and the lower priority given to SPEAR by SLAC staff continued to cause cancellations of synchrotron radiation runs, which left SSRL with severe oversubscription troubles and a long list of users whose experimental runs could not be accomplished. In a gesture of generosity, during 1989, three other synchrotron radiation laboratories (NSLS, SRC, and the NSF-funded Cornell High Energy Synchrotron Source, CHESS) offered to accommodate SSRL users on the basis of their proposals accepted by SSRL. Forty-one experiments were accommodated by the NSLS, eight by CHESS, and four by the SRC. The magnitude 7.1 earthquake on October 17, 1989, also “was not kind to SSRL,” causing misalignment of the SPEAR ring and associated disturbances to experimental equipment and some downtime. PEP operation was also suspended for some months after the earthquake, thus disabling the parasitic synchrotron radiation program there as well.¹⁵³

The SSRL–SLAC Relations Revisited

A May 1988 study of the management relationships at SSRL and SLAC, conducted by SSRL staff member William Wilken at the behest of SSRL director Bienenstock, examined the situation on the SLAC site and the variety

150. SSRL Activity Report 1987.

151. SSRL Activity Report 1988.

152. P. A. Wolff (chairman of the SSRL science policy board) to Donald Kennedy (president of Stanford University), 9 Sep 1986, SLAC Archives, Richter series 7, Box 4, Folder 1.

153. SSRL Activity Report 1989.

in expectations and demands placed on the labs by various stakeholders. The DOE, used to the oversight of large projects and installations, had gradually come to adopt a view of SLAC/SSRL as a multipurpose laboratory that should be managed through a single contract. Any obstacles to this were “Stanford’s to solve, from the DOE point of view.” At stake were “annual expenditures of \$100–\$150 million,” the soon-opening “mammoth” SLC facility, as well as “world leadership in synchrotron radiation.” The SSRL, based on its own experience, was “treated as a second-class citizen at the site” and worked predominantly “in a reactive mode” because when proactive, it met “considerable resistance from SLAC.” SSRL also noted that “users are seriously impacted by unstable operational schedules” due to the lack of SSRL participation in scheduling and day-to-day “resolution of difficulties”; furthermore, the costs of dedicated time on SPEAR were judged to be “unpredictable and excessive.” SSRL was barred from participating in the long-term planning of operations on the SLAC site and simultaneously “too small to go it alone entirely in big projects,” which was an essentially unsustainable situation. SLAC, for its part, was very much shaped by the “concept of a single-purpose, focused, dedicated high energy physics laboratory” that had “been paramount since SLAC’s inception and for many, the only way to execute truly successful programs.” To many people at SLAC, “SSRL is an enigma; an unplanned, unasked for event” that was accepted only as long as the activities were “below the noise level in terms of impact”—it was “seen by many as a drain on SLAC resources.” Also according to the study, Stanford University had very different approaches to SLAC and SSRL, with the former always seen as “outside the normal aegis of the University” and its faculty “largely disconnected from the teaching function and the normal departmental affiliation,” whereas SSRL “emerged from a departmental orientation and because of broad inter-disciplinary interest, has strong ties with several departments through joint faculty appointments or through research projects” and was therefore “considered very much a part of the University.” Officials of other DOE laboratories, interviewed for the study, communicated the impression “that all was not well at the SLAC/SSRL site” and that “SLAC had made a mistake by retaining a single-purpose laboratory position. Without diversification it now is facing serious problems of existence—what comes after SLC?”¹⁵⁴

154. William Wilken, “Analysis of the Management Relationships at the Stanford Linear Accelerator Center and Stanford Synchrotron Radiation Laboratory Site,” 28 May 1988, SLAC Archives, Richter series 7, Box 6, Folder 6.

This last question was picked up by Bienenstock in an April 8, 1989 letter to Bob Byer, Vice Provost and Dean of Research at Stanford. Concluding that those “knowledgeable about the LEP project [the Large Electron Positron Project at CERN] expect that LEP’s capabilities will surpass those of SLC some time during this calendar year,” which would mean that “there will be considerably less justification for the priority afforded to SLC than there presently is,” Bienenstock speculated that perhaps the future for SLAC lay rather with synchrotron radiation than HEP.¹⁵⁵ Somewhat carelessly made, this speculation gave rise to strong negative response at SLAC, in itself testimony to the delicacy of the matter. Addressing all SLAC faculty in a April 28, 1989 memo, Bienenstock wrote that there were indications that “several of you interpreted my memo of 8 April 1989 as a declaration of war,” which “is quite unfortunate, as that was not the intent of the memo.” Explaining that his prime responsibility as SSRL director was the health of the synchrotron radiation program, in the short term as well as over the long term, Bienenstock argued that the recent years of operations instability of SPEAR had taken SSRL “from being the world’s premiere synchrotron radiation laboratory to being the butt of jokes about our failure to function.”¹⁵⁶

CUTTING LOOSE AND JOINING

The Solution to the Second X-Ray Drought

As the interest in SPEAR by high energy physicists waned due to the PEP and SLC facilities (and other accelerators domestically and abroad, such as the LEP at CERN, the Tevatron at Fermilab, and the planned SSC), there was indeed little reason for SSRL to continue to subordinate its scientific ambitions to the rule of the SLAC HEP program. Among others the DOE, working purposefully to develop and consolidate U.S. capability in synchrotron radiation, questioned this state of affairs. Changes to the organizational relationship between SSRL and SLAC would wait another couple of years, but the technically determined hierarchy at SLAC with the linac as injector of particles to

155. Arthur Bienenstock to R. Byer (Vice Provost and Dean of Research at Stanford), “A Single M&O Contract for SSRL and SLAC,” 8 Apr 1989, SLAC Archives, Richter series 7, Box 6, Folder 6.

156. Arthur Bienenstock, memo to SLAC faculty, “SLAC/SSRL Single Contract,” 28 Apr 1989, SLAC Archives, Richter series 7, Box 6, Folder 6.

all other machines, inevitably limiting SSRL's control over its operations of SPEAR, was to be changed sooner.

Already in 1986, it had become clear to the SSRL and the DOE that in order to solve the issue of the second X-ray drought and meet the needs of the user community, SSRL would have to take full control over SPEAR operations, detach it from the linac, and install a separate injector. A proposal to the DOE was submitted in late 1986 and was swiftly approved.¹⁵⁷ Construction of a 3 GeV synchrotron injector started in February 1988, together with several other improvements of the technical performance of SPEAR.¹⁵⁸ These upgrades not only allowed but necessitated the full dedication of SPEAR to the synchrotron radiation program, and in October 1990 all HEP operations on SPEAR ceased.¹⁵⁹ In a letter to the DOE in September 1989, Bienenstock considered the role of SSRL for the approaching decade and noted that with the upgrades, the separate injector, and the full dedication, SPEAR "will be the only DOE storage ring, other than PEP, with any significant number of straight sections available for X-ray wiggler beam lines until the Advanced Photon Source at Argonne National Lab is operating." SSRL would hence, wrote Bienenstock, serve "the large Western need for X-ray synchrotron radiation," a mission that required a funding increase allowing for appropriate staff increases to make possible full-time operation and maintenance of SPEAR once SLAC ceased its half-time responsibility for the ring. The proposed increase of the operating and research budget was to "go smoothly from \$10.1 M in FY89 to at least \$16.5 M in FY91, with corresponding increases in the other budget categories."¹⁶⁰

Although the injector was only under construction and SPEAR hence still dependent on the linac for injections, the spring 1990 synchrotron radiation run on SPEAR was named "one of the two or three best in SSRL's history," with record-level technical performance and overwhelmingly positive responses from users as expressed in end-of-run summary forms.¹⁶¹ These achievements and the future prospects of a dedicated SPEAR with a separate injector surely helped to mitigate the effects of the mixed reviews of SSRL in the aforementioned 1989 DOE report, where SSRL had been criticized for

157. Cantwell, "20 Years of SSRL" (ref. 72).

158. SSRL Activity Report 1988; SSRL Activity Report 1989.

159. SSRL Activity Report 1990.

160. Arthur Bienenstock to Robert O. Hunter (Director, Office of Energy Research, Department of Energy), 8 Sep 1989, SLAC Archives, Richter series 7, Box 6, Folder 6.

161. SSRL Activity Report 1990.

“clubbiness or elitism” among its staff and for limitations on operations stability and reliability.¹⁶²

In 1991 the new SPEAR injector was commissioned, and on February 17, 1992, SSRL began its first user run as a fully dedicated synchrotron radiation facility.¹⁶³ The injector functioned satisfactorily from day one: “In the first twelve weeks of dedicated user running an average of 89.8% of the scheduled beam was delivered to users.” SSRL was finally a full-fledged user facility comparable with other independent synchrotron radiation laboratories elsewhere. With 26 experimental stations, in 1992 the SSRL served 280 experiments run by 550 individual experimenters, mainly from domestic universities and government labs but with some presence of both industry and research institutes from abroad. “Operation went smoothly, with only 3.4% unscheduled down time. There were problems with beam stability but, overall, users were extremely pleased with the quality of operations.”¹⁶⁴

The DOE-Driven Reexamination of the SSRL–SLAC Relationship

The process to physically detach SPEAR from the SLAC main linac in order to provide for an eventually independent and fully dedicated SSRL synchrotron radiation facility occurred in parallel with another transformation that also, in retrospect, might seem inevitable.

Clearly, the troubles of SSRL in the mid- to late 1980s were not merely technical but also organizational, such as its relationship with SLAC. In a letter to Stanford University president Donald Kennedy on September 9, 1986, the chairman of the SSRL SPB, P. A. Wolff, claimed that SSRL “has serious problems” with its relationship to SLAC, and that these problems lay not primarily at the level of scientists and technicians, where “cooperation between the two laboratories is good,” but rather at the managerial level, where “interaction has deteriorated in the last year, and is now poor.” This situation “is complicated by DOE’s proposal to fund the two laboratories through a single contract, and seeming pressure to merge them.” Such a merger, argued Wolff, should not be undertaken during the current startup phase of SLC, a “tense time for SLAC”; were they to merge, the director of the combined laboratories would not be able to give SSRL adequate attention, “or

162. “Synchrotron Facilities” (ref. 148); SSRL Activity Report 1990.

163. SSRL Activity Report 1991.

164. SSRL Activity Report 1992.

to promote its interests in the face of the overriding primary objective of the SLC program.”¹⁶⁵

Though SSRL needed a change in the mid-1980s, becoming a (minor) part of an enlarged SLAC organization did not seem like the right solution. However, DOE officials kept pushing for the sake of its own convenience. In its view, two separate and rather different contracts with Stanford University for operations on the SLAC site was an overly complicated arrangement, whereas a merger of the labs would mean a better focus for the DOE-sponsored activities on the SLAC site, some cost savings, and a streamlining of overall operations on the site.¹⁶⁶ In addition, in 1984 Richter had succeeded Panofsky as director of SLAC, and oral testimonies suggest that Richter had already made up his mind regarding the long-term future of SLAC and decided that synchrotron radiation was an inevitable part of that future, and thus emerged as an influential advocate of a SLAC/SSRL merger.¹⁶⁷ Richter himself even claims to have “conspired” with the DOE to make SSRL a part of SLAC, against the will of most everyone else, especially the SSRL directors and staff, who, according to Bienenstock, were “very fearful” of Richter gaining control of the lab and starting to “suppress our needs.”¹⁶⁸

Between 1986 and 1992, a number of consecutive committees, mainly consisting of SLAC and SSRL faculty and with occasional participation of other SLAC and SSRL staff and directors, reviewed the different possibilities and options that might come into question regarding an alteration of the status of SSRL and its relationship to SLAC. In the spring of 1986, a faculty committee concluded, among other things, that “if the director of SLAC becomes the director of a major, multi-disciplinary enterprise,” it would “lead to a diversion of attention on his part”; furthermore, the single-mission operation of SLAC was considered beneficial to SSRL since SLAC thus shared responsibility for accelerator operation for SSRL while not being at all involved in its scientific program.¹⁶⁹ An ad hoc administrative committee on possible SLAC/SSRL

165. Wolff to Kennedy, 9 Sep 1986 (ref. 152).

166. Bill Gough (Director, DOE Stanford Site Office) to Burton Richter, 27 Feb 1987, SLAC Archives, Richter series 7, Box 6, Folder 5; Burton Richter, memo to files, “Conversations with Bill Gough and Gerry Lieberman,” 22 Jan 1985, SLAC Archives, Richter series 7, Box 6, Folder 5.

167. Bienenstock, interview (ref. 88); Lindau, interview (ref. 88).

168. Burton Richter, interview by author and Thomas Heinze, 22 Mar 2013; Bienenstock, interview (ref. 88).

169. “Final Report of the Faculty Committee on SLAC/SSRL Unification,” 15 Jul 1986, SLAC Archives, Richter series 7, Box 6, Folder 5.

unification, appointed by Richter in late 1987, was specifically asked not to consider “technical, programmatic or managerial issues” but focus on administrative topics. It cited a number of smaller obstacles to unification, but saw many opportunities as well. Recommending unification on the basis of the principle of letting “the two laboratories maintain separate identities,” the committee’s conclusions largely echoed the DOE’s arguments of efficiency and better focus.¹⁷⁰ The 1988 Wilken study, mentioned above, arrived at similar conclusions but highlighted the cultural differences between the two labs, noting that a merger seemed “unacceptable to almost everyone except the DOE.” Wilken recommended a preserved organizational status quo, at least throughout the next 2–3 years of “intense activity” (the opening of SLC, the construction of the separate SPEAR injector), but concluded that “all of the recommendations are supportive of and point to an eventual single multi-purpose laboratory.”¹⁷¹

Meanwhile, the DOE only seemed to intensify its campaign to merge the two labs—in 1989 both Stanford President Kennedy and SLAC director Richter noted in correspondence with each other, with Bienenstock, and with SLAC faculty, a renewed interest on behalf of the DOE to renegotiate and merge the contracts for SLAC and SSRL, which in the view of DOE officials would be to the benefit of both labs.¹⁷² Yet another committee, assessing “operational and organizational” aspects of a SLAC-SSRL unification, delivered its report in April 1989, recommending a single unified SLAC/SSRL laboratory with synchrotron radiation “the mission of a single, separate division” created out of the present SSRL with as little change as possible and “represented by an associate director in the Laboratory directorate.” The user support organizations for HEP and synchrotron radiation “should remain separate and should report to the laboratory director and the appropriate associate director.”¹⁷³

170. “Report of the Ad Hoc Administrative Committee on Possible SLAC/SSRL Unification,” 29 Feb 1988, SLAC Archives, Richter series 7, Box 6, Folder 6.

171. Wilken, “Analysis” (ref. 154).

172. Donald Kennedy to Burt Richter and Arthur Bienenstock, 10 Mar 1989, SLAC Archives, Richter series 7, Box 6, Folder 6; Burton Richter, memo to SLAC directorate, faculty, and committee members, “The Question of SLAC/SSRL Unification,” 16 Mar 1989, SLAC Archives, Richter series 7, Box 6, Folder 6.

173. M. Cornacchia et al., “Operational and Organizational Committee Report,” 24 Apr 1989, SLAC Archives, Richter series 7, Box 6, Folder 6.

A May 1989 report by the SSRL SPB concluded that, given the ongoing work of commissioning of the SLC, the SPEAR upgrades, and the completion of the new injector, a merger of the two labs in the nearest future “would not be in the interest of either organization.”¹⁷⁴ By this, Stanford seemed convinced to try to maintain the status quo so as not to present the two labs with “an unnecessary distraction” during a time of demanding infrastructure upgrade work, and informed the DOE in September 1989 of their recommendation “that the two laboratories not be unified at this time.” From the point of view of the university, “the scientific benefits of such a unification are not sufficiently clear to proceed at this time.”¹⁷⁵ With these assessments seconded by SSRL and SLAC directors, the issue seemed to be at least temporarily resolved, and for the time being, SSRL and SLAC would remain separate organizations.

Final Organizational Move: Merger in 1992

But the DOE did not bow. In 1990 and 1991 intensified efforts on their behalf spurred further discussions of a merger among directors and officials of SSRL, SLAC, and Stanford University. In February 1991 the SSRL Affiliated Faculty held a special meeting to discuss a merger, and decided to recommend that a single joint DOE contract be established in order to improve the SSRL position in the DOE system. The recommendation was not that SSRL become a division of SLAC but rather that the two be kept “as independent laboratories reporting to administrators on campus as is presently the case but both under the same contract.”¹⁷⁶ However, real unification of SLAC and SSRL appeared increasingly unavoidable, and the SSRL director appeared to have been convinced during 1991. In a joint memo to all SSRL and SLAC Faculty and Staff dated August 26, 1991, Richter and Bienenstock explained that in light of the successful completion of the SPEAR injector and the transfer of SPEAR to SSRL for operations and maintenance, their revisiting of the issue of “unifying SLAC and SSRL under a single contract as a single laboratory,” and

174. “Report of the SSRL Science Policy Board,” 2 Jun 1989, SLAC Archives, Richter series 7, Box 7, Folder 8.

175. Robert L. Byer (Vice Provost and Dean of Research, Stanford University) to Donald K. Stevens (Associate Director Basic Energy Sciences, Office of Energy Research, Department of Energy) and Wilmot N. Hess (Associate Director, Office of High Energy & Nuclear Physics, Department of Energy), 14 Sep 1989, SLAC Archives, Richter series 7, Box 6, Folder 6.

176. William Spicer to Bob Byer (Dean of Research, Stanford University), 25 Feb 1991, SLAC Archives, Richter series 7, Box 6, Folder 7.

their discussions with faculty and senior staff of both laboratories, they had concluded that it would now be “mutually beneficial to unify the two laboratories.” The two directors announced that Stanford President Kennedy had informed the DOE that it was the university’s preference that SSRL become a division of SLAC, “and that the SSRL Director be a SLAC Associate Director,” when the DOE contract for SLAC was to be renewed on October 1, 1992. The two directors cited a mutual interest of the two labs in each other’s future, and voiced their “belief that cooperative accelerator and instrumentation research is best fostered within a single laboratory setting,” simultaneously recognizing “that the very great achievements of SLAC and SSRL have come through almost single minded devotion to their respective fields,” which led them to expect “that the high energy physics and synchrotron radiation scientific programs will remain almost completely independent.” There would, therefore, be “no major changes in the SSRL structure or organization,” although “the reorganization will alter significantly the way in which SLAC and SSRL interact.”¹⁷⁷

Importantly, the details of the merger still had to be worked out, and the consent of all parts of the organizations mobilized. A joint SLAC-SSRL Faculty Committee, headed by SLAC faculty member Martin Perl, drafted a document with “recommendations for a merged SLAC-SSRL,” which was presented on November 13, 1991. The document, whose content was largely adopted as a framework for the merger of the labs, stipulated that SSRL would indeed remain an independent laboratory in the shape of a division of SLAC, with its director retaining the title “Director of the Stanford Synchrotron Radiation Laboratory” and also becoming an Associate Director of the merged SLAC-SSRL. Noting “the dominant cultural differences” between HEP and synchrotron radiation science,” the committee recommended that the SSRL division of SLAC retain its influence and control over “SPEAR operations, maintenance, modifications, and improvements; beam line planning, construction, maintenance, and operations; technical support to users; and scientific research.” With regard to the joint SLAC-SSRL contract under negotiation between Stanford and the DOE, it was the committee’s opinion that the future “united oversight board” for SLAC regulated in this contract should “contain adequate representation for the synchrotron radiation sciences.” Finally, the

177. Burton Richter and Arthur Bienenstock, memo to all SSRL and SLAC faculty and staff, “Single SLAC/SSRL Contract,” 26 Aug 1991, SLAC Archives, Richter series 7, Box 6, Folder 7.

committee recommended “that the name of the merged SLAC-SSRL remain the Stanford Linear Accelerator Center,” since “the SLAC Faculty is reluctant to change the name.”¹⁷⁸

On October 1, 1992, SSRL became a division of SLAC and Bienenstock an associate SLAC director. In his “All Hands Memo” of that date, Richter wrote that the integration “gives the opportunity to build on the strengths of what used to be two separate laboratories to develop even more effective programs to the benefit of both,” and that he was “enthusiastic about the opportunities opened by this integration.”¹⁷⁹ The October 1992 *SSRL Users Newsletter* viewed the merger as a “contractual and administrative merger” and foresaw that it “should have very little effect on users, since the SSRL Division will have full responsibility for managing the SPEAR accelerator complex and the SSRL user program.” The newsletter cited “initial indications” that the merger was “proceeding smoothly,” and further noted: “Cooperation and common planning are developing at all levels, with each part of the now-broader laboratory working for the vitality and health of all its parts. This is particularly exciting as a number of new proposals for the site are of interest to both the synchrotron community and the high energy physics community.”¹⁸⁰ With SPEAR under its control and organizationally a division of SLAC, the days of SSRL as the parasites were effectively over.

CONCLUDING DISCUSSION

The October 1, 1992 transition was only an organizational one—certainly, there are other ways of analyzing the changes to the relationship between SSRP/SSRL and SLAC than merely through the changes in their (formal) organizational links, and thus also several other meanings for the word parasitic. In the case of the use of SPEAR, the parasitism ended before 1992—partially already in 1979, and fully in 1990. The end of a parasitic relationship in terms of scientific communities represented at SLAC is harder to define in

178. Martin Perl, “Final Draft from SLAC Members of Joint SLAC-SSRL Faculty Committee,” 13 Nov 1991, SLAC Archives, Richter series 7, Box 6, Folder 7.

179. Burton Richter, “All Hands Memo,” 1 Oct 1992, SLAC Archives, Richter series 7, Box 6, Folder 8.

180. “SSRL Merges with SLAC,” *SSRL Users Newsletter*, October 1992, SLAC Archives, 2000-024 series, Box 1/3, Folder 20.

time, not least since, as this article has shown, the growth of SSRL in size (number of users; number of instruments on SPEAR) and ambitions/scope was gradual. Therefore, it must be the first conclusion of this article that the meaning of the word parasitic is not clear-cut but dynamic, varying greatly with perspectives and explanatory ambitions.

This variety in the meaning of parasitic corresponds, in a sense, to the complexity of the whole story of the growth of synchrotron radiation at SLAC, a story that has been told here from the perspective of the micro-level actors and interests that drove this growth and the rearrangement of the scientific priorities of SLAC for twenty years. The multiple meanings of parasitic can be used to contrast the various forms of interdependence and independence between the organizational actors in the story—the SSRP/SSRL, SLAC, Stanford University, the NSF, the AEC/ERDA/DOE—and how they interacted to preserve their own interests (and existence, in the case of SSRP/SSRL, and to some extent in the case of the single-mission HEP laboratory SLAC). The various organizational and scientific/technical moves by SSRP/SSRL throughout the story—the switch from NSF to DOE, the half-time dedication of SPEAR, the detachment of SPEAR from the SLAC linac, and the eventual incorporation of SSRL into SLAC—mark various endings of parasitism and involve the interests of several actors whose roles in each instance can be interpreted very differently and need an exhaustive historical account and contextualization to be done adequate justice.

The intention to tell the story from this particular perspective was provided in the introduction: Too often have historical accounts of the institutional transformation of large scientific facilities and labs been framed only in a macro-level context of structural changes to science, science policy, and society in the second half of the twentieth century, and too seldom has the tenacious work of micro-level actors and their comparably small-scale ambitions of scientific achievement within groups and departments been invoked to explain change in science. This article set out to do exactly that—not replacing or disallowing grand narratives of change and their importance in understanding institutional transformation and renewal, but complementing them. In this sense, the meticulously detailed accounts of local affairs negotiating change in incremental steps fulfill their purpose and a rather predictable conclusion can be drawn: There is no straightforward explanation as to why the synchrotron radiation activities at SLAC made it successfully through all hurdles and obstacles, shook off the role as parasites, and eventually took over as the core experimental activity at SLAC.

But the article's consistent micro perspective necessitates a deeper concluding discussion about these micro forces and what type of change they actually brought about. It is far too simple and imbalanced to claim that there was no long-term vision or strategy at all among the actors whose incremental efforts of exploring the potential of synchrotron radiation for various scientific uses eventually made SSRL into a national resource and part of the core activities of SLAC. Among the initiators of SSRP, and the scientists who took part in the pilot program and the buildup of the first beamline, surely there were visions of a national synchrotron radiation facility. The NSF, which granted the SSRP a total of almost \$4 million in only four years (1973–77, see Table 2), clearly had a long-term vision for these investments. In the 1980s, when the scientific successes of the SSRP/SSRL appeared to have infused its directors with a self-confidence verging on hubris, the visions of a purpose-built and very large synchrotron radiation source optimized for hard X-rays on the SLAC site seems to have created a sense of dissatisfaction and discontent among those users of synchrotron radiation from SPEAR who saw the already squeezed technical and scientific support structures further diverted by these bold plans. Perhaps vision rather worked in disfavor of long-term change?

The coproduction of a myriad of smaller initiatives, detailed in the narrative as presented above, suggests as much: Real forces of change appear to have come from below, from small-scale ambitions of exploring scientific opportunities and responding prudently and sensibly to the requests of scientific users. The visionary macro-level actors—be they NSF, DOE, SLAC, or Stanford—seem largely to have contributed with opportunities and constraints that the micro-level actors could make use of, miss, abide, and overcome. Clearly, this discussion is now dangerously close to a counterfactual account of what might have occurred if visions had been expressed otherwise and opportunities and constraints materialized in other shapes. And there lie the limits with regard to what a retrospective analysis of change can accomplish. This article has sought to present an alternative historical narrative of change, consistently staying at the micro level and crediting the small-scale ambitions and capabilities of directors, managers, research leaders, scientists and technicians at SSRL, SLAC, Stanford, NSF, DOE, and elsewhere with an ability to contribute to long-term change by their actions and deliberations at the local and momentary level. As a piece of historical research on the profound institutional transformation of a key component in the postwar U.S. mobilization in science, the article fills an important function by communicating this alternative view on change, and supports this

view by not seeking to replace but rather to complement existing similar historical analyses.

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