After the War: Women in Physics in the United States

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To Robert Howes and Leonardo Herzenberg: models for the supportive husband every married woman physicist needs.

Contents

Preface

A casual reader of the history of physics might easily conclude that there were only a handful of active women physicists in the United States until well into the 1970s. Even the authors, in their earlier work, were surprised when they found more than 300 women who had done technical work on the development of the first atomic bomb*. The current volume focuses on our study of quite a number of women physicists who were professionally active from the end of World War II until the early to mid 1960s. We limited our study to this time period because it was 1963 which saw the publication of *The Feminine Mystique* which marked the reactivation of the women's movement in the United States, which in turn led to many changes in the status of women. Career and educational opportunities opened for women in many areas including physics. Affirmative action became a mandate for federal agencies and a priority for industries seeking government contracts.

In the process of preparing this manuscript, we have identified many fascinating women physicists who were working in the years after World War II and greatly enjoyed their stories. We learned how they managed to overcome the many obstacles to careers in physics posed by the society of the time. We hope that the reader will find them as interesting as we did.

* This work was published by Temple University Press as *Their Day in the Sun: Women of the Manhattan Project* in 1999.

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Author biographies

Ruth H Howes*

Ruth H Howes is Professor Emerita of Physics and Astronomy at Ball State University. She holds a PhD from Columbia University where she did her dissertation work under the direction of C S Wu. She retired from Ball State as the George and Frances Ball Distinguished Professor of Physics and Astronomy in 2003 and served as Professor of Physics and Chair of the Physics Department at Marquette University until 2008 when she moved to Santa Fe, New Mexico. She has held a Foster Fellowship at the US Arms Control and Disarmament Agency where she worked on verification and intelligence and a AAAS Congressional Fellowship during which she worked on the staff of the Senate Labor and Human Resources Committee then chaired by Senator Edward Kennedy. She has served as president of the American Association of Physics Teachers and the Indiana Academy of Science and as a program officer at the National Science Foundation. Her primary research has been in nuclear physics, lately the structure of very neutron-rich isotopes of light elements. She also worked as deputy chair of the National Task Force on Undergraduate Physics and as one of two project directors of the Strategic Programs for Innovation in Undergraduate Physics and the workshops that followed beginning after her retirement. She is a fellow of the American Association of Physics Teachers, the American Physical Society and the American Association for the Advancement of Science.

Caroline L Herzenberg

Caroline Herzenberg is a physicist who has achieved recognition for her activities relating to women in science as well as for her scientific work.

Born in New Jersey in 1932, she grew up in Oklahoma. As a high school senior in Oklahoma City, she became a winner of the Westinghouse Science Talent Search. She graduated from Massachusetts Institute of Technology with an SB in physics. For graduate study she attended the University of Chicago, where she worked in experimental physics under the guidance of her thesis advisor, Dr Samuel K Allison, and was awarded a PhD in 1958.

She has conducted both basic and applied research and worked in diverse areas including low-energy nuclear physics, Mössbauer spectrometry, instrumentation development, arms control, and technological emergency preparedness; and she was a principal investigator for returned lunar sample analysis for the Apollo 11 and Apollo 12 missions.

* Photograph by Anton Brkić

She has taught on the faculties of several universities, including Illinois Institute of Technology, the University of Illinois at the Medical Center, and California State University, Fresno. She was a senior scientist on the staff of IIT Research Institute, and worked as a physicist on the staff of Argonne National Laboratory until her retirement.

Dr Herzenberg is the author or coauthor of over 100 scientific and technical papers and chapters and articles in books, and is coauthor with Ruth Howes of the book *Their Day in the Sun: Women of the Manhattan Project* and author of the book *Women Scientists from Antiquity to the Present*. She is a past president of the Association for Women in Science, and a fellow of the American Physical Society and of the American Association for the Advancement of Science.

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Ruth H Howes and Caroline L Herzenberg

Chapter 1

Introduction. The setting for women in physics after World War II

Prior to World War II, some significant advances in physics took place in the United States, but the number of physicists was small, and the number of women physicists was extremely small. Hiring practices and anti-nepotism rules generally barred married women physicists from university, industrial and even high-school jobs. During and after World War II, both the practice of physics and the situation of American women underwent enormous changes. Throughout this period, the number of women in physics grew, but it has remained low to the present day.

During World War II, the work of most of the physicists in the United States was focused on defeating the Axis powers through work on wartime military projects, three of the most important being the development of radar, sonar and nuclear weapons. World War II was even referred to as 'the physicists' war'. In general, women were encouraged by the government to work in support of the war effort, and the military quickly hired female college graduates with some scientific knowledge. Rosie the Riveter was the poster girl for the effort to get American women into the work force.

At the end of World War II, the US government feared that the flood of returning soldiers seeking jobs would throw the country back into a financial depression. Consequently, the government launched two efforts that significantly affected women: (1) a publicity campaign to encourage women to leave the workforce and care for their families, thereby providing job openings for the returning men; and (2) the GI Bill, a law that provided a range of benefits for returning World War II veterans, encouraging returning soldiers to further their education and thus delay their entry into the work force. The GI Bill attracted large numbers of men to college, helped build the US system of research universities as well as its industrial workforce, and opened up opportunities for educated women and men to teach at college level.

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Women also took advantage of educational opportunities available through the GI Bill. For example, Marjorie Peason enlisted as a WAVE (Women Accepted for Voluntary Emergency Service—a corps of women who enlisted in the US Navy and served in shore jobs freeing men for sea duty) specifically to get a college education. She worked in Washington on predicting the weather for the Pacific battlefields and Japan. On being discharged in 1946, she spent one week at home and then enrolled in the University of Minnesota to study electrical engineering [1]. The publicity campaign to direct women into homemaking instead of paid employment was more harmful to women in physics because women physicists were generally professionally oriented and uninterested in wearing high heels while vacuuming, and they were unwilling to forsake their interest and professional activities in science.

The end of World War II was soon followed by the beginning of the Cold War, a state of elevated military tension between the powers of the Western and Eastern Blocs, which ramped up in 1947 and continued for over 40 years, until about 1991. As a result, military research and development continued, initially somewhat downscaled from the level during World War II, but soon exhibiting appreciable growth. Research began in additional areas of physics, notably condensed matter physics.

By the late 1940s, the number of students majoring in physics had more than doubled from prewar levels. Demand for physicists continued to outstrip supply well into the 1960s. In a poll conducted in the early 1960s, Americans ranked 'nuclear physicist' as the third most prestigious occupation. However, the situation for women was somewhat different. While many women, almost 90, were awarded doctorates in physics over the postwar decade, the fraction of female PhDs in physics declined to one in 40, and the fraction of women in the profession of physics generally, to one in 25 [2, p 371]. The proportion of women receiving advanced degrees in physics fell by a factor of two between the prewar and postwar decades [3].

Thus, the climate for all physicists, and particularly for women physicists, changed rather abruptly at the end of World War II. Physics grew very quickly, but it branched in many directions, so telling the stories of women who worked in physics after the war is more complex than telling the stories of women who worked on the three great projects of World War II [4].

In the early aftermath of World War II, there were at least three major arenas that impacted heavily on the work of all physicists: the politics of science, military developments usually tied to the Cold War and its arms race, and technical developments that changed the ways physics was done. The story of American women in physics is set against the background of these changes and was strongly influenced by them. Table 1.1 presents the major political events that affected women in physics after the war.

At the end of World War II, the military managed and funded the government's wartime research establishment, notably the group of military research laboratories that included Los Alamos, Oak Ridge, Hanford and other sites used for the design and production of nuclear weapons. On 1 January 1947, the McMahon Act transferred the control of this system of laboratories and associated sites to a civilian agency, the Atomic Energy Commission (AEC). When the McMahon Act

Table 1.1. Politics of science after World War II.

Timeline for the politics of science after World War II	
Servicemen's Readjustment Act (GI Bill)	22 June 1944
Establishment of first National Lab—Argonne	1 July 1946
McMahon Act (Atomic Energy Act)	1 August 1946
The transfer of control of nuclear production to AEC	1 January 1947
McCarthyism	1948–56
The Korean War	25 June 1950–27 July 1953
Establishment of National Science Foundation	10 May 1950
Oppenheimer hearing	12 April 1954
Brown vs Board of Education	17 May 1954
Establishment of NASA	1 October 1958
Publication of *The Feminine Mystique*	1963

separated the development, production and control of nuclear weapons from the military, military aspects were taken over by the Armed Forces Special Weapons Project. The AEC was charged with setting the direction of the research done in the facilities it controlled, on weapons as well as on civilian uses of nuclear technology, and also for any other research programs established. The AEC was additionally responsible for stocking the US arsenal with nuclear weapons. The new agency had to develop a management strategy for individual sites, as well as an overall strategy for its programs. It is no wonder that this was a turbulent time at the Manhattan Project sites, which would later evolve into the National Laboratory System, a system of centralized national laboratories funded by the public and charged with research and development to benefit both the military and the public welfare. Argonne National Laboratory, which had initially been formed to carry out Enrico Fermi's work on nuclear reactors as part of the Manhattan Project, was designated as the first national laboratory in the US on 1 July 1946 [5].

Research developed rapidly at universities around the country, where the military funded new buildings with laboratories staffed, in many cases, by scientists who had worked on the Manhattan Project. The returning GIs flooded classrooms and left the colleges and universities very short of teaching staff. The National Science Foundation (NSF) was created on 10 May 1950 to support research based on scientific merit rather than potential civilian or military applications, and the NSF supported a great deal of academic research.

The Cold War brought what seemed like almost unlimited funding for research in several areas of physics, including nuclear and particle physics. Corporations as well as governments also began to realize how important materials science could be to them. Physics research, no matter how basic, seemed to be a magic bullet for the development of new technologies. However, at the same time the Cold War brought on a wave of fear of aggression from the communist bloc of nations led by the Soviet Union. As a consequence, security measures in science became more stringent, resulting in barbed wire and guarded gates at some research sites, and more security restrictions on information release for topics such as research on fissionable elements, with further restrictions on publication [6]. Suspicion and security regulations drove many scientists to quit government laboratories. The Red Scare, which promoted fear of left-leaning politics and questioned the loyalty of individual scientists, was led by Representative Joseph McCarthy of the House Un-American Activities Committee (HUAC). This changed the demographics of science in the US as various universities fired faculty members who refused to sign loyalty oaths or discuss the politics of their colleagues and friends with HUAC. On 12 April 1954, the scientific leader of the Manhattan Project, J Robert Oppenheimer, was deemed a security risk after a hearing before the AEC and was refused a security clearance, an action that divided the physics community.

This time period also marked the Soviet Union's launch of Sputnik, the beginning of the space race and the establishment of the National Aeronautics and Space Administration (NASA) on 1 October 1958. NASA would employ many physicists, including some notable women, in subsequent years.

World War II also radically changed the way that physics was conducted. During and after the war, the government acquired an unprecedented role in the funding of research. The resources available became enormously larger. Furthermore, the separation between pure research and applied research and technology became blurred. Before World War II, almost all advances were due to one scientist working on her (or his) own or with a very few colleagues. It was often funded by the researchers themselves or interested wealthy individuals. After World War II, this approach became the exception rather than the rule, and physics entered the era of Big Science, which continues to the present day, with concomitant bureaucratization [6]. In 1950, the American Institute of Physics publication *Physics Today* noted that 'The springtime of Big Physics has arrived' [2, p 378].

At the end of World War II, the US had no assembled nuclear weapons. That changed rapidly, as shown in table 1.2. Los Alamos, Hanford and Oak Ridge set to work to remedy this situation by producing a number of weapons based on early nuclear fission designs and beginning design work on more efficient nuclear fission weapons for special purposes. Laboratory directors at Argonne and Oak Ridge also

Table 1.2. Nuclear weapons after World War II.

Timeline for nuclear weapon developments after World War II	
US arsenal: no implosion bomb assembled	1 September 1945
Soviets test of a fission weapon	29 August 1949
Program to develop hydrogen bomb started	30 January 1950
US test of thermonuclear device at Enewetak	November 1952
US arsenal of 841 nuclear weapons, total yield 50 megatons	End of 1952
First Soviet test of a thermonuclear device, Joe 4	12 August 1953
US test of first hydrogen bomb at Bikini Atoll	1 March 1954
US arsenal 5 543 nuclear weapons, yield 17 546 megatons	End of 1957

began to develop nuclear reactors for use in the production of civilian electric power. Laboratory directors at the weapons laboratories argued forcefully for the support of general nuclear research at their facilities because (1) research results might be critical for future weapons development and (2) unless scientific staff had the opportunity to conduct basic research, the most capable scientists would migrate to the developing research universities. The AEC continued these policies immediately after its creation in 1947.

On 29 August 1946, the Soviets tested a nuclear fission weapon well before the US had anticipated it could. (It turned out that the Soviet spy system had provided its nuclear scientists with information on the Manhattan Project, greatly shortening the development time for Soviet nuclear weapons.) The discussion of what to do about the Soviet success involved many physicists, with some, notably Oppenheimer and Fermi, advocating the development of more powerful and sophisticated fission weapons and others, led by Edward Teller, advocating a crash program to develop a weapon based on nuclear fusion which, it was anticipated, could have almost unlimited power. In early 1950, President Truman announced a crash program to develop a thermonuclear (fusion) weapon, the hydrogen bomb. Both the US and the USSR successfully developed and tested such weapons. By the end of the decade, US and Soviet arsenals held thousands of nuclear weapons.

It was also well-established that atmospheric testing of nuclear weapons released radioactive isotopes into the atmosphere. Public fear of nuclear radiation drove support for stopping nuclear testing and by 1963 both governments had agreed on the Limited Nuclear Test Ban Treaty which forbade atmospheric testing. After this, the weapons laboratories developed methods for underground nuclear testing and began to diversify their research portfolios beyond the production and development of nuclear weapons.

Among the new technical developments, there was no device that had a greater impact on physics or was more closely associated with physicists than the computer. Many women were active in computer development, but the story of the computer is a saga in its own right and will not be treated here.

A major contributor to the development of computers was the advent of solid-state electronic devices, specifically the coming of the transistor, which was announced by Bell Telephone Laboratories in late 1947. This led to the replacement of vacuum tubes, which were relatively large and operated at higher voltages, by transistors, which operated at lower voltages, emitting much less heat. The use of transistors also made circuitry much more reliable. The development of the transistor caused a boom in solid-state electronics and spawned the growth of an industry in which many of the major companies supported active research laboratories. Integrated circuits followed in the late 1950s and then microprocessors in the late 1960s and 1970s. The large industrial research laboratories competed with the National Laboratories and the research universities. They provided employment for many physicists and also created a demand for students with technical training. The miniaturization of circuit components enabled by the transistor also made it more feasible to launch spacecraft and contributed to the acceleration of the space race.

Studies in condensed matter physics continued, with some successes and hopes for additional advances in areas such as high-temperature superconductivity, which seemed to promise new and very useful technological applications. The discovery of the Lamb shift in 1947 led to increased interest in quantum electrodynamics.

Additional developments in physics included the invention of the laser in 1958, and further progress took place in many other areas, notably in understanding the nucleus, the fundamental forces and elementary particle physics. Women physicists worked in all these areas. Women were especially active in astronomy and astrophysics as they had traditionally been.

Obviously we have omitted any number of technical developments, but this limited list concentrates on those developments that most affected women physicists.

We will discuss two major classes of women physicists in subsequent chapters. First, a number of women physicists worked on military projects, while others worked in the universities or industrial laboratories while the war was in progress. After the war, some of these women continued in research in areas such as nuclear weapons and nuclear reactor development, some switched into new fields such as health physics and played key roles in their development, and a few dropped out of physics. The second set of women consisted of members of a generation of women who finished their degrees during the war years. They entered the workforce in the late 1940s and early 1950s. They played significant roles in the new large industrial laboratories and in the growing field of condensed matter physics. They also did significant work at NASA and contributed to the educational reforms in science that followed the launch of Sputnik. Like their male colleagues, some of these women suffered for protecting their colleagues and friends from the harsh investigations of the HUAC.

We have organized the stories of these women according to the institutions that employed them. This grouping is necessarily arbitrary, particularly since many of the women we discuss changed jobs and worked in more than one research field during this period. We choose it because it highlights the types of work and the importance of the work that women physicists conducted during the late 1940s and 1950s, and assists us in telling their stories.

We limit our discussion largely to the late 1940s and 1950s, as is evident from the time lines above, although tracing individual careers requires going outside this time limit. During the 1960s, the civil rights and women's movements began to affect all workplaces. Moreover, the physics conducted in the National Laboratories changed with the signing of the Limited Test Ban Treaty in August 1963, and physicists there began to focus on issues of safety and the verification of arms control agreements, as well as new ways of producing energy. The development of the personal computer, which also dates from the early 1960s, vastly changed the way in which physics was done, as did the construction of very large accelerators in dedicated facilities. All these developments affected the work that women physicists did and the character of the physics workforce. While we include some minimal discussion of physics and physicists in the 1960s and later, this book focuses on the challenges and successes of women physicists in the years immediately following World War II, before the eras of affirmative action and the personal computer.

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