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Mobilizing US physics in World War I

Johannes-Geert Hagmann

In applying their research to wartime problems, US physicists changed the relationship between physics, the military, and the government.

On 6 April 1917, the US formally declared war on Germany and entered the conflict that would become known as World War I. Conventional wisdom holds that it was "the chemists' war," due in large part to the infamous use of chemical weapons in combat. However, other sciences—including physics—were also crucial, most notably in the development of detection technologies and countermeasures.¹

Although the legacy of World War I physics is not as well known as the legacy of chemistry, the wartime experience changed a generation of US physicists. This article traces the history of physicists' mobilization and stories of their scientific engagement during the Great War. The conflict significantly advanced the prominence and political influence of physicists in the US, and the impact of their work can be seen well into the postwar period.

Scientific preparations for war

"I cannot tell you how sincerely I regret that you have been compelled to leave your laboratory and take part in the work of the army. The war is causing appalling losses, and I sympa-

thize most deeply with all who are compelled to bear them. May peace soon be restored, bringing with it the happy life of the past!"²

Those words, written by US astrophysicist George Ellery Hale (pictured in figure 1) to a German colleague in late 1914, expressed the simple wish of a distant observer: the hope for a rapid return to the normality of prewar scientific life. Hale's desire would remain unfulfilled. After the dreadful loss of

tens of millions of lives, the complete devastation of large regions in Europe, and political turnabouts following the armistice, neither the world nor scientific life would revert to its prewar state.

As the National Academy of Sciences' (NAS's) foreign secretary, Hale maintained intensive contacts with scientists in other countries, including Germany, during the first years of the war. But Hale and his colleagues would not keep their observer's position for long. Although the US maintained political neutrality through the spring of 1917, US scientists and engineers started early on to seek solutions to military problems raised by the war—and they actively prepared for entrance into the conflict.



CYNTHIA CUMMINGS

US PHYSICS IN WWI

The scientific and technological mobilization of the US began shortly after the outbreak of war in Europe. That mobilization reached new levels of urgency after the sinking of the British ocean liner *Lusitania* by the German Navy in May 1915, in which around 1200 people, including 128 US citizens, perished. Shortly after the attack, Thomas Edison suggested establishing an experimental laboratory for the US Navy. His initiative triggered the formation of the Naval Consulting Board. The board consciously avoided cooperating with academic institutions because its members believed academic research did not provide anything of practical use. Instead, the board decided to review inventions and technical improvements by civilians, and it received more than 100 000 suggestions.³ The majority, however, were of poor quality, and only a single project was realized during wartime.⁴ Its outcome, the Ruggles orientator, was a moving preflight trainer for new airplane pilots. In short, Edison's experiment in crowdsourcing public knowledge for technical armament had failed.

Another attempt at scientific preparation was launched by Hale in April 1916 through the NAS. The academy affirmed its provisional support to President Woodrow Wilson in the event that the country entered the conflict. To that end, the NAS founded the National Research Council (NRC) to coordinate fundamental and applied research for defense purposes and to support the interdisciplinary collaboration of scientists and engineers. Hale was made the council's first chairman.

Hale, Millikan, and the Chicago connection

"War should mean research, not reports," Hale wrote to a colleague in 1916.⁵ That short statement gives a strong sense of Hale's goals in forming the NRC and pushing for scientific mobilization.

The centralized coordination of research through the NRC followed the example of European academies and organizations. In July 1916 Hale traveled to England to study the mobilization of British and French scientists. Reporting his findings to Wilson, he argued that "the brains . . . that today are necessary to the output of munitions were needed yesterday, and will be needed again tomorrow, for the arts of peace."⁶ Hale envisioned a much more powerful and permanent role for the NRC in postwar times. Historians of science thus view him as a postwar systems architect for scientific research in the US.⁷

Personal contacts with foreign scientists helped Hale and his staff to establish the political influence of the newly formed NRC. In May 1917 a group of physicists from Britain and France, among them Ernest Rutherford, recipient of the 1908 Nobel Prize in Chemistry, visited the US to inform their American colleagues about their research on submarine detection technology. That transfer of knowledge gave US scientists a head start on their own detection development. In addition, the

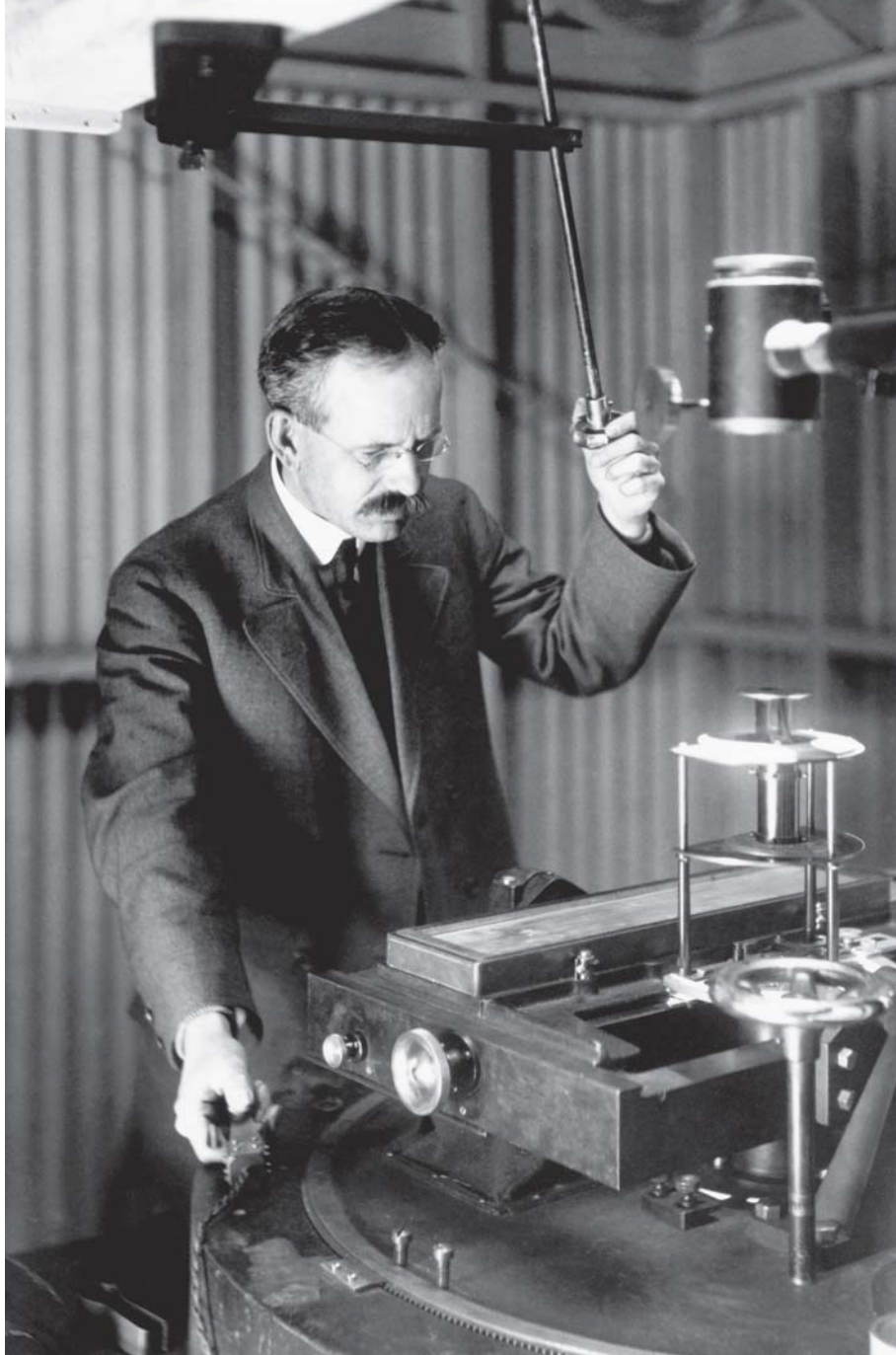


FIGURE 1. GEORGE ELLERY HALE at the Mount Wilson Observatory. (Courtesy of the Archives, California Institute of Technology, and the AIP Emilio Segrè Visual Archives.)

foreign group also lobbied for the mobilization of US research. To support that cause, Rutherford issued a memorandum to Wilson and US secretary of war Newton Baker that described the death of his former student Henry Moseley at the Battle of Gallipoli. Moseley's case served as a striking example of the loss of scientific talent, and Hale drew on Rutherford's story to urge the US to make sure talented researchers were mobilized for wartime science rather than lost on the battlefield.

Hale was the mastermind behind the creation of the NRC, but physicist Robert Millikan (pictured in figure 2), who served as the vice chairman, shaped much of its wartime work. Millikan and Hale had worked together at the University of Chicago with Albert Michelson, the head of its Ryerson Physical Laboratory (figure 3).

After the creation of the NRC, both Hale and Millikan halted

their scientific work to oversee the new organization in Washington, DC. Hale left the capital in August 1917 to supervise the installation of a 100-inch telescope—then the largest in the world—in the Mount Wilson Observatory in Pasadena. The observatory became part of what Hale called the “Pasadena War Laboratories,” a network of several institutions including Mount Wilson that helped build precision instruments for the US Army and Navy. By the end of the war, the staff at the observatories had added more than 60 new employees to help make range finders, periscopes, and geodetic instruments.

In Washington, Millikan acted as Hale’s right hand for the daily business of the NRC, but he kept in touch with former colleagues and students at the Ryerson Physical Laboratory. In 1916 the physics department faculty at the University of Chicago consisted of Millikan, his former mentor Michelson, three younger professors, one instructor, and four assistants. Later that year members of the department were drafted for service in France, for research in the US Signal Corps, and for work with the chemical division of the NRC. Through his interference with service assignments, Millikan in all likelihood helped several researchers to avoid injury or death in combat. Industrial researcher Frank Jewett would argue in 1918, however, that the war had disrupted fundamental research and the training of the next scientific generation by deploying scientists from academia and industry for the “war’s scientific sweat-shop.”⁸

The Physical Sciences Committee

After its formation, the NRC subdivided its operation into seven committees, each dedicated to a branch of the sciences. In addition to serving as vice chairman, Millikan became the head of the Physical Sciences Committee. Because it was decentralized and did not have its own facilities, the committee relied on cooperation with industrial laboratories, universities, colleges, and military research units. To facilitate the joint work of the NRC with the military, Millikan was appointed as a major in the Signal Corps and was put in uniform. He was initially amused by this transformation and mocked his training, which included weekly pistol practice. It later turned out, however, that his new status was invaluable when negotiating between academic and military stakeholders.

In early 1917, several weeks before the US formally entered the war, the NRC received a long list of scientific and technological questions from the technical departments of the army and the navy. NRC scientists started to work on roughly two dozen physical problems that they hoped would affect the course of the war. More than 50 scientists were put to work on developing wireless communication, ranging airplanes and gunnery, camouflage, airplane instruments, and more. By the end of the war, the NRC had studied roughly 70 projects.

In view of the devastating attacks on Allied ships, the most urgent problem for physical research was the development of methods for submarine detection. The US antisubmarine project is considered the first large-scale military R&D program.⁹ In total, 10 research groups took part.

Submarine detection methods fell into two categories: passive detection with microphones and other listening devices and active detection through reflection of sound waves. As the operation of submarines became quieter and therefore more difficult to detect through passive devices, French and British researchers initially considered the possibility of active detec-

tion through ultrasonic echo ranging. The new technology allowed the listening vessel to detect enemy positions by sending out signals that would bounce off the surface of a submarine. French members of the Allied research committee reported that the ultrasonic experiments conducted by Paul Langevin used piezoelectric transducers. Building on those findings, US ultrasonic research was carried out at Columbia and Stanford Universities, and by a new research group in San Pedro, California. Despite this effort, however, a practical ultrasonic ranging device could not be put into combat before the end of the war.

An early group dedicated to listening methods was established at Nahant near Boston. Funded by the Naval Consulting Board, the unit began studying listening technologies to be tested in sea trials. It was supported by teams of engineers from the General Electric and Western Electric Companies, including chemist and future Nobel Prize recipient Irving Langmuir.

However, Millikan was convinced that detection was first and foremost a physics problem, one that would need to be complemented by engineering at a second stage. The NRC therefore established a second physical research group in New London, Connecticut, to work on the submarine problem. The team

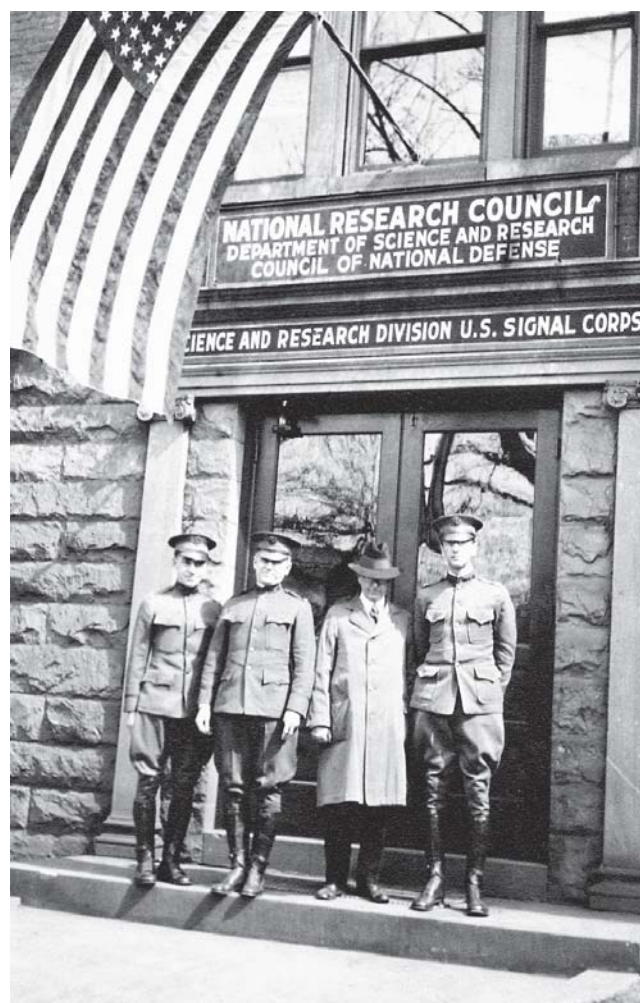


FIGURE 2. ROBERT MILLIKAN (second from left) in 1918 in front of the NRC office in Washington, DC. (Courtesy of the Archives, California Institute of Technology.)

included young scientist Vannevar Bush, who would later head the wartime research of World War II through the US Office of Scientific Research and Development. Based on the findings of British and French scientists, mathematician Max Mason proposed an improved detector in July 1917. The physical improvement involved a particular geometrical arrangement of listening tubes, the so-called multiple variable or M-V tubes, whose working principle gave rise to other instrument designs.

In addition to participating in wartime research in laboratories, some US physicists also worked in Europe. To continue the exchange of scientific information between Allied countries, in late 1917 Millikan dispatched liaison officers to Britain, France, and Italy to report scientific intelligence to the Research Information Committee of the NRC. As a notable example of US physicists in combat, Augustus Trowbridge of Princeton University and Theodore Lyman of Harvard University assumed the leadership of a sound- and flash-ranging mission in France.

Lyman organized a ranging school near Langres and eventually was designated the officer in command for a battalion of more than 1000 men.¹⁰

Progress in optics, struggles in acoustics

Aside from centrally supervised projects such as the investigation into submarine detection, several individual physicists committed themselves to more narrowly defined problems. Among them was Michelson, the head of Millikan's laboratory in Chicago. Michelson was a physicist of German descent who had immigrated to the US as a two-year-old (see the box on challenges German immigrants faced during World War I). He was a graduate of the US Naval Academy, and having both military and scientific training made him unusual among civilian physicists.

As the nation's first recipient of the Nobel Prize in Physics, Michelson was an eminent figure in the scientific community. Millikan initially appointed Michelson to lead the submarine

VIEWS ON THE ENEMY FROM WITHIN

In the late 19th and early 20th centuries, more than 20 million immigrants entered the US, the majority coming from southern, eastern, and central Europe. In 1910 Americans of German extraction accounted for around 8% of the population. After the US entered World War I in 1917, anti-German sentiment became widespread, as reflected in this 1917 military recruitment poster by Harry Ryle Hopps. Questions arose about the loyalty of the country's minorities and about how to deal with enemy aliens.

As historian David Laskin has shown, public and government scrutiny of minority groups was unnecessary; in general, immigrants proved to be loyal. However, suspicion of German immigrants was widespread. Furthermore, enemy aliens and immigrants not intending to become US citizens were exempt from the draft, which created resentment among those likely to be drafted.¹⁴

Doubts and mistrust were also present in the scientific community. Some Allied scientists tended to draw a picture of a homogeneous scientific population in Germany. The manifesto "To the Civilized World," which declared the signatories' explicit support of German military actions, was signed in October 1914 by 93 German professors and intellectuals, including physicists Max Planck and Wilhelm Röntgen. The document became a focal point of criticism by Allied scientists throughout the war.¹⁵

US physicists were left with difficult choices. Many of them had completed part of their scientific education in Europe, very often in Germany. Robert Millikan, for example, had spent almost a year in Berlin before finding his scientific home in Chicago. After

the outbreak of war, he was shocked by intelligence reports on German war atrocities in Belgium. Millikan's autobiography claims that while in Berlin, he foresaw the savagery Germany would carry out in the first half of the 20th century¹⁶—though the accuracy of Millikan's account is somewhat contested (see the article by Michael Fletcher Perry, *PHYSICS TODAY*, May 2007, page 56).

An example of a physicist in Millikan's Chicago group who faced a particularly difficult personal situation was Otto Koppius. A German immigrant who became a naturalized US citizen in 1912, Koppius saw his descent as a handicap. After the outbreak of war, he appealed to Millikan for the chance to participate, ideally in battle action in France, to prove his loyalty beyond any doubt. Millikan, however, advised him to stay in the academic system and to contribute to war efforts by teaching physics.

Conflicts over political positions would also occur in Millikan's private life. In August 1917 his son Glenn became embroiled in an argument with his friend Paul Nitze over Nitze's fierce pro-German position, which was shared by Nitze's father, University of Chicago linguistics professor William Nitze. Millikan urged the older Nitze to "choose whom you will serve. If you choose the enemies of this country then considerations of your own safety will at least cause you to stop the spread of an infection which endangers you as well as the United States. If



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after all your heart of hearts is here then a full knowledge and realization of the situation will bring at once the remedy."¹⁷ Paul Nitze would later become a key strategist of US defense policy during the Cold War.

Secrecy and loyalty at US research labs were also concerns. Through careful selection of candidates, George Ellery Hale sought to avoid hiring scientists with pro-German tendencies. In early 1917 Millikan noted that physicists were accustomed to communicating with foreign colleagues and warned National Research Council committee members to take the matter of secrecy seriously, as he considered "the German system of espionage to be remarkably complete and efficient."¹⁸



FIGURE 3. MEMBERS OF THE RYERSON PHYSICAL LABORATORY in June 1916. Notable members include Robert Millikan (first row, right), Albert Michelson (first row, second from right), and Otto Koppius (fourth row, right). (Courtesy of the AIP Emilio Segrè Visual Archives.)

detection group in New London. Michelson, not feeling “equal to the job,”¹¹ quickly stepped down from that responsibility and proposed that he study problems more closely related to his research interests.

In 1918 Michelson joined the US Naval Reserve at the rank of lieutenant commander and soon began to research improved optical range finders with the support of the National Bureau of Standards, then headed by another former Chicago physicist, Samuel Stratton. Since the beginning of the war, the bureau had been trying to help remedy a severe supply problem—a shortage of high-quality optical glass. Before the war, the US had been largely dependent on the importation of optical glass from Germany. Through intensive testing and development, the US managed to turn from dependency to self-supply at industrial scale later in the war. During the war’s last months, the US was even able to export excess capacities to Italy.

The National Bureau of Standards was also responsible for the quality control of glass products, a natural fit for Michelson’s research interests. As early as 1891, Michelson had filed a patent for a naval optical range finder. During the war, he collaborated with an optician to improve its performance. Michelson hoped to improve transmission despite multiple deflections inside the instrument. Furthermore, building a range finder took almost a full year, and simplifications in manufacturing were therefore badly needed.

Like previous range finders, Michelson’s instrument relied on the principle of optical coincidence. The target object was gauged with two offset telescopes whose images were unified in the eye of the observer. The offset in the image caused by

parallax was corrected with deflecting prisms. Michelson’s proposal included several modifications of the instrument’s basic outline; those changes resulted in a larger field of view and the possibility of using longer base lines to increase the precision of the apparatus. The navy adopted Michelson’s improved range finder, and it appears that the results were more than satisfactory. Hale reported from Mount Wilson in the summer of 1918 that his workshop would start with the production of mirrors for 30 units.

Another of Michelson’s ideas was less successful. Concurrently with his optical research, he joined forces with the physician John Wilson to develop a new ear protector. The heavy use of bombs in confined battlefields led to numerous hearing injuries. Michelson and Wilson searched for a device that would use a mechanical valve to dampen the pressure wave caused by gunnery while simultaneously letting the human voice pass through mostly unfiltered.

The first samples of the ear protector were made from a combination of soft and hard rubber, along with metallic components. The protective device formed an airtight seal around the soldier’s ear (see figure 4). A small, slightly folded aluminum shield transmitted sound waves through the device. On the arrival of a strong pressure wave, such as the sound of a bomb, the shield would push against a spring that closed the device’s inner valve and thus protect the eardrum.

Initial estimates for the production costs of the device were low, and the design seemed highly promising for future application. In reality, however, animal testing and subsequent autopsies showed that the device lagged behind other available models at preventing hearing loss.¹² In a study of such devices,

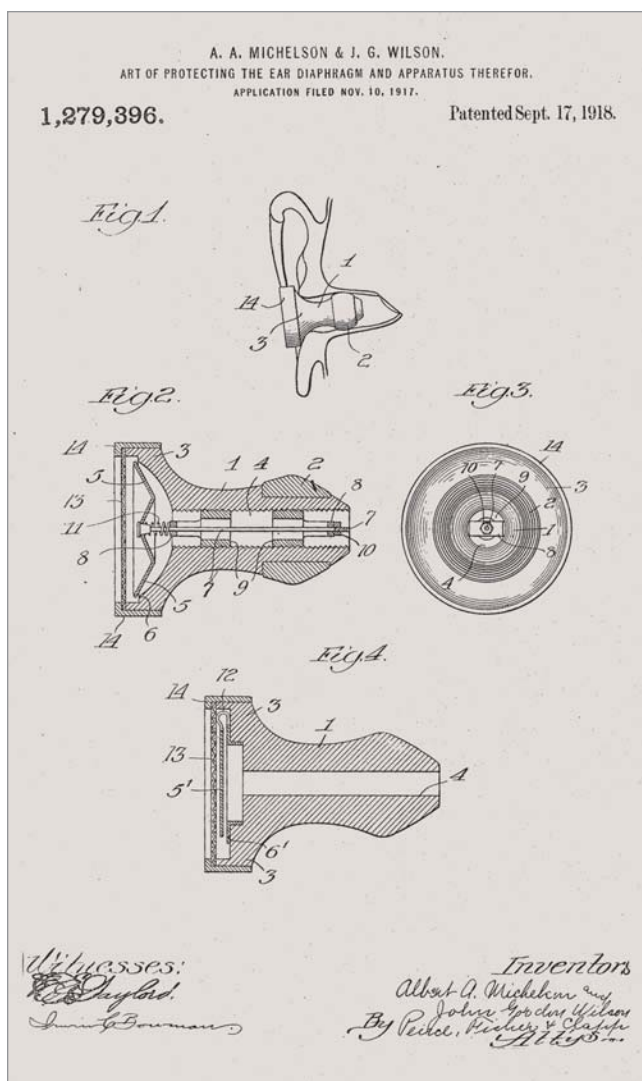


FIGURE 4. A DIAGRAM OF THE WILSON-MICHELSON EAR PROTECTOR. (Courtesy of the US Patent Office.)

the Wilson-Michelson ear protector finished sixth out of seven. Only the simple use of dry cotton wool performed worse. The army did not pursue mass production of Michelson's protector, despite its ability to let wearers hear human voices.

The war's legacy for physics

None of those studies would have a profound effect on the course of the war. Because the US entered the war late, many projects could not be finished or brought to scale before the armistice was signed in November 1918. Moreover, some projects—like Michelson's ear protector—did not lead to significant improvements over existing technology.

Physics did not alter the course of the war, but the war changed perceptions of physics, its organization, and its power in postwar America. Several US physicists engaged in international scientific committees and associations, and the position of the NAS for institutional research was strengthened. Millikan's nomination for the Nobel Prize in Physics by Hale and Michelson not only highlighted his scientific merit but also un-

derlined his key role in the organization of wartime research. Another of the war's enduring legacies was the NRC. Hale's brainchild still exists, and it now produces influential reports aimed at guiding US science policy and public opinion.

Furthermore, as Hale had predicted, the war acted as a political catalyst for the community of physicists and encouraged the dual use of their intellect for war and for peace. Hale nicely summarized the outcome of the scientific war effort when he wrote, "One of the most notable results of the war is the emphasis that has been laid on the national importance of chemistry and physics."¹³ Physicists who had been involved in research during the war, including Millikan, Bush, and Jewett, would go on to act as political advisers, science administrators, and policymakers in the following decades, most notably during World War II. The wartime experience of US physicists and engineers supported the political breakthrough of a new scientific elite.

World War I thus became a transformative episode in the history of the American physics community, a development that historian Daniel J. Kevles has chronicled in remarkable detail in the commanding classic *The Physicists*.³ The reduced distance between physics and the military in the War to End All Wars, and the subsequent entanglement of scientific, industrial, and military research, would reveal their consequences in the later armed conflicts of the 20th century. Scientific and technological research, including major contributions from physics, became a decisive factor in warfare.

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