INTRODUCTION

IN THE FALL of 1927, Edward Condon, a twenty-five-year-old theoretical physicist who had just returned to the United States from Germany steeped in the new quantum mechanics, walked away from a promising academic career at his alma mater, the University of California at Berkeley. He went to work instead at the Bell Telephone Laboratories, the newly established research and development (R&D) arm of the American Telephone and Telegraph Company (AT&T), in New York City. Condon explained the rationale for this decision to Raymond Birge, a respected spectroscopist and his graduate advisor. "I hope to devote myself to theoretical physics in a broad way if my capabilities may permit it," he wrote Birge in November. "You probably smile at such a boyish hope in these days of great specialization[,] but nevertheless I intend to struggle to keep broad even if at a sacrifice of considerable depth."[1]

Birge did not understand Condon's logic. "There are certain types of very practically minded persons who may be . . . happier in industrial work than in University work," he responded flatly. "But in the case of a theoretical physicist like yourself, I cannot understand how there can be any question at all."[2] Condon resigned from the Bell Telephone Laboratories early in 1928 to pursue a university career, but his abiding interest

in the industrial applications of physics persisted. His brief exchange with Raymond Birge evolved into an ambitious program of university-industry collaboration that directly challenged prevailing attitudes within the scientific and business communities about the legitimacy of academic science in a corporate setting. In the fall of 1937, after he had spent nearly ten years on the physics faculty at Princeton University, Condon moved to Pittsburgh to become associate director of research at the Westinghouse Electric and Manufacturing Company, the second largest electrical equipment maker in the United States. He left Westinghouse for Washington, DC, in 1945 to head the Commerce Department's National Bureau of Standards, a civilian government agency founded in 1901 to serve as the custodian of weights and measures.

This book explores the birth, life, and death of Condon's vision of cooperative research in industry through economic depression, world war, and the looming Cold War. It rose to prominence in Pittsburgh, a leading hub of heavy manufacturing in the United States. For years, Westinghouse and other large firms in the electrical and chemical industries had maintained elaborate laboratories stocked with university-trained scientists and engineers to protect their established product lines and diversify into new markets. This type of institutionalized invention proliferated after World War I, in no small part because of the synergies that existed between R&D and manufacturing. Some firms, however, also adopted a longer-term perspective; they exploited what contemporary practitioners called fundamental or basic research. This type of research aimed at product development, but it lacked the same institutional pedigree. More speculative studies sometimes proceeded without the internal guidance that seasoned managers, established markets, and core scientific and technological strengths readily afforded.[3] In 1935, Westinghouse plunged headlong into nuclear physics, a new field still confined to university laboratories, on a scale unknown in the electrical industry. This commitment to cutting-edge academic research lacked precedent among Pittsburgh's other smokestack industries, where R&D owed its legitimacy as an essential corporate function to the new knowledge gleaned from more established fields in the scientific and engineering disciplines.[4] When he arrived at Westinghouse two years later, Condon found a research environment uniquely suited to his temperament and sensibilities.

Condon's central role in the growth of fundamental research at Westinghouse adds a new and largely unexplored dimension to the history of industrial R&D in the United States. Much of the historical literature—

especially the pioneering studies of AT&T, the General Electric Company (GE), and the E. I. du Pont de Nemours and Company—highlights the strategies that these and other firms employed to reconcile the professional standards of academic research and the commercial imperatives of the corporate laboratory.[5] The extent to which Westinghouse absorbed and put to use Condon's knowledge of quantum theoretical physics deepens this historiographical tradition. Fields that straddled both communities and yet remain largely unexplored in the historical literature, such as solid-state physics (broadly known as the physics of solids before World War II), populated from the outset Condon's vision of cooperative research.[6] Crucially, however, Condon also conceptualized his new job in Pittsburgh in strikingly different terms than his predecessors and contemporaries elsewhere. Rather than see the diffusion of science into industry as a process of accommodation between academic and corporate interests, he articulated a wholly new strategy that transcended professional boundaries and rigid categories of knowledge production.

Condon often used terms such as "fundamental" and "pure" science and "basic" and "applied" research in his writings and public pronouncements to explain how new knowledge could be put to practical use, but he did not privilege any one of them at the expense of the others. Instead, he employed these terms interchangeably as symbols or rhetorical cues to converse in the languages of science and engineering, to translate ideas and skills from one community of practitioners to another to solve practical problems.[7] That conceptual breakthrough structured his understanding of and prescription for scientific and technological progress in industry. It emerged inchoate at the Bell Telephone Laboratories in the late 1920s, reached full maturity at Westinghouse Electric a decade later, and collapsed under the weight of military priorities at the National Bureau of Standards after World War II.

In the opening address he delivered at the dedication of the Charles Benedict Stuart Laboratory of Applied Physics at Purdue University on June 19, 1942, Condon proclaimed, "We must resolve not to neglect the cultivation of the basic science which we hope some day to apply. More and more, industry in America is recognizing the debt it owes to fundamental science—a debt it can hope to repay by fostering more basic research in its own research laboratories and by working in close cooperation with the universities." Elaborating further, he dismissed the notion of a research hierarchy in this collaborative process. "I feel sure," Condon declared, "that those who are interested with furthering scientific research

at colleges see this problem of applied physics in all its broad implications. They recognize, as we do in industry, that all physics is applied physics—so- called pure physics being simply that part whose application is to satisfy the curiosity of the physicists."[8] Statements like this one guided Condon's approach to R&D at Westinghouse and within industry as a whole.

Shortly after he arrived in Pittsburgh, Condon established a postdoctoral fellowship program to recruit, on a rotating basis, young PhD scientists to conduct research on topics of their own choosing. On the face of it, he did not introduce anything radically new. Consulting arrangements, sponsored research projects, and other modes of collaboration among academic and industrial scientists and engineers had originated in the United States during the second half of the nineteenth century and proliferated after World War I.[9] The fellowships reinforced these established patterns of behavior, but they also broke new ground. A first for the electrical industry and for a firm reared in a long tradition of practical research, Condon's organizational innovation made the systematic introduction of open-ended studies in disparate and seemingly esoteric scientific fields, such as nuclear physics, a vital corporate asset. He expected Westinghouse to benefit from cutting-edge academic expertise and the universities to acquire, through the employment of former postdoctoral fellows, a workforce specifically attuned to industry's scientific interests. World War II abruptly ended Condon's local experiment in university-industry cooperation as the demand for military hardware crowded out fundamental research, and it also permanently restructured the political economy of science in the United States. Universities no longer relied so heavily on wealthy individuals and corporate sponsors for financial support after the war.[10] As the Cold War deepened, they more often looked to the federal government, especially the defense establishment, for resources to diversify and expand academic research in the physical sciences and engineering disciplines.[11]

Against this backdrop, Condon left Westinghouse to head the National Bureau of Standards in Washington, DC. Despite their pervasiveness as the primary units of analysis in the Cold War historiography, universities did not experience the impact of new patterns of patronage in isolation while the Bureau of Standards and other government research agencies languished passively on the sidelines as repositories of scientific and technological backwardness. Historians have reinforced that perception by way of uncritical analysis or outright omission.[12] Several possible scenarios of what the federal scientific research establishment might look like in the future began to emerge at the end of World War II.[13] The postwar revital-

ization of the Bureau of Standards that Condon spearheaded on behalf of business and industry competed directly against other initiatives designed to optimize the relationship between science and the state. Perhaps the best known among them is the contentious debate that culminated in the establishment of the National Science Foundation (NSF). The two main protagonists, West Virginia senator Harley Kilgore and Vannevar Bush, wartime director of the Office of Scientific Research and Development (OSRD), articulated opposing visions of public support for science. The delayed enactment of the NSF's founding legislation, which languished until 1950, allowed the military departments to fill the void left by the dismantling of the government's temporary wartime R&D contracting agencies.[14] Always present but rarely observed in this historical narrative is the role played by a third protagonist—Secretary of Commerce Henry Wallace, scion of a progressive Iowa farming family and an ardent New Dealer who ran the Department of Agriculture in the 1930s and occupied the vice presidency during the war. Wallace allied himself with Kilgore in the NSF debate.[15] However, he also acted independently to remake the Commerce Department—by way of the Bureau of Standards—into a complementary source of science-based economic growth.

The programmatic charge that Wallace handed to Condon at the Bureau of Standards in 1945 embodied a broader rethinking of late New Deal economic policy. World War II had pulled the United States out of the Great Depression, as industrial production and factory employment surged to meet the matériel demands of the armed forces. The cancellation of military contracts at the end of the war, however, stoked fears of another downturn, a possibility that alarmed Henry Wallace and other liberal reformers who had witnessed firsthand the economic dislocations of the 1930s. Always suspicious of but not inherently opposed to big business, Wallace believed that large corporations, which had fulfilled the bulk of production quotas for the wartime mobilization, leveraged their patent holdings and in-house R&D capabilities to manipulate markets and restrict competition at the expense of smaller firms without similar technical resources. Unlike some of the radical elements of the New Deal who continued to favor direct intervention in the economy to break up large firms and prevent a return to prior patterns of corporate behavior, Wallace and other like-minded advocates of national planning—while not unsympathetic to the thinking behind these measures—understood the problem of postwar reconversion in terms of stimulating consumption rather than regulating production. Opposed to the wholesale restructuring of capi-

talist institutions, they envisioned sustained peacetime economic growth and full employment as the natural outcomes of fiscal policies designed to increase purchasing power and consumer demand.[16] In his new role as secretary of commerce, Wallace anticipated the same economic dividends from public investment in R&D at the National Bureau of Standards. The improved competitive performance of small firms promised to raise the productive capacity of industry as a whole and to stimulate the consumption of goods and services in an expanding national economy.

Hired to rebuild the Bureau of Standards scientifically and overcome its reputation for second-rate research, Condon faced the added challenge of pulling off this transformation in a restructured political economy in which national security programs consumed an increasingly large share of the federal R&D budget. The onset of the Cold War recast Wallace's conception of an activist state in strictly military terms. It also set limits on Condon's ability to exploit, on the bureau's behalf, the type of university-industry collaboration he had established in Pittsburgh to broaden the scope of research at Westinghouse. Public investment to stimulate technological innovation in small businesses became a military subsidy for weapons R&D that no longer prioritized the importance Wallace had initially placed on firm size. His prescription for postwar prosperity quickly faded as Condon obtained seemingly limitless defense resources to diversify R&D at the bureau and bypass chronic bureaucratic constraints on institutional growth.

Condon's career at Princeton, Westinghouse, and the National Bureau of Standards is analyzed here in seven chapters that combine biographical and institutional history. Chapter 1 sets the stage for Condon's industrial career at Westinghouse. It traces his life from humble beginnings in New Mexico Territory at the turn of the twentieth century to the pinnacle of professional accomplishment in quantum theoretical physics at Princeton University in the mid-1930s. The origins of quantum mechanics in Europe, the transmission of this new knowledge to the United States, and the rapid growth of the discipline within the academic physics community structured his intellectual and professional development during this period.[17] So did a brief interlude at the Bell Telephone Laboratories, where Condon observed firsthand how scientists and engineers in a corporate setting applied their knowledge and skills to the solution of practical problems.

The technical resources manufacturing firms in Pittsburgh exploited to develop new commercial products did not incorporate the type of physics research that Condon cultivated at Princeton. Chapter 2 explains why

Westinghouse challenged this conventional wisdom and how it prepared to take advantage of Condon's scientific skills. Pittsburgh's history is inextricably linked to the rise and fall of the materials processing and machine tool industries. Condon's career at Westinghouse broadens that historical narrative. Rather than focus on the familiar inputs of capital and labor, the chapter explores the pervasive but largely unknown role of science in the growth and diversification of the local economy.[18] Shortly before Condon left Princeton, Westinghouse added to its R&D repertoire a new research paradigm that incorporated to a far greater extent than before the trappings of an academic physics department. In this case, Condon's absence from the chapter story line is deliberate. It is necessary to understand how Westinghouse and the industrial community in which it resided and in many ways emulated accommodated the unique brand of industrial research that he brought to Pittsburgh in the late 1930s.

Chapter 3 puts Condon back into the narrative. Unlike many of his academic peers who did not consider the benefits of an industrial career sufficiently enticing to give up their university appointments, Condon relished the opportunity to expand fundamental research at Westinghouse. He anticipated a more satisfying professional experience that complemented rather than diminished his academic pedigree in theoretical physics. Through such novel innovations as the postdoctoral fellowship program, Condon transformed the Westinghouse Research Laboratories into a significant source of new knowledge in nuclear physics, mass spectrometry, the physics of solids, and microwave electronics that impressed industrial rivals and universities alike. An explicit expression of the narrow specialization he had always avoided, the fellowships also served a vital corporate interest. Condon appropriated the company's engineering and manufacturing expertise to translate the results of research in these disparate fields into products for sale to academic and industrial consumers.

Chapter 4 examines the technological outputs of Condon's strategic vision, as well as the extent to which they succeeded in the marketplace. On the eve of World War II, scientists had already begun to exploit radioisotopes produced in high-voltage accelerators to treat diseases in the same way their predecessors had taken advantage of x-ray tube technology to improve medical diagnostics. Condon tuned the nuclear physics program at Westinghouse to the same practical ends. His corporate handlers, however, saw limited potential for commercial growth in the field, despite initial enthusiasm for the in-house research that supported it. Their response exposed in stark terms a clear disjunction between management's

tolerance for risk and Condon's optimistic predictions for new business opportunities. His ability to converse in the languages of science and engineering succeeded up to a point; knowledge produced in the laboratory did not seamlessly transition into commodifed technologies for a mass market. Mass spectrometry research followed the same abortive trajectory. Only the research Condon started in the physics of solids and microwave electronics, two fields that bore some connection to the company's core technological strengths, moved quickly from the laboratory to the factory floor.

Chapter 5 focuses on the extent to which military requirements narrowed the focus of fundamental research on problems that dovetailed nicely with Westinghouse's expertise in engineering and manufacturing. Condon spearheaded the growth of microwave R&D, which propelled the company to fifth place (in dollar sales) among all US makers of radar equipment during the war.[19] He also served briefly as J. Robert Oppenheimer's handpicked deputy to organize the Manhattan Engineer District's secret atomic weapons laboratory at Los Alamos, New Mexico. A longer assignment at the University of California helped Westinghouse meet short-term production goals to scale up the manufacture of weapons-grade uranium for the bombs assembled at Los Alamos. It did not, however, become the permanent corporate R&D presence in Berkeley that Condon had envisioned and pressed his superiors to establish as a logical extension of the prewar fundamental research program in Pittsburgh. Already less sanguine about the prospects of a bright future at Westinghouse, Condon turned his attention to the politics of postwar atomic energy policy. This abrupt shift in priorities during the summer of 1945 culminated in a meeting with Secretary of Commerce Wallace, who selected Condon to head the National Bureau of Standards.

Condon's six-year tenure at the Bureau of Standards is the subject of chapter 6. From the outset, he modeled the bureau's transformation into a nationally recognized technical resource for the small business community on the founding principles of the fundamental research program at Westinghouse. This initiative foundered on restrictive civil service requirements, low staff salaries, a reputation for useful but unimaginative research, and the competition for resources in a federal R&D establishment increasingly dominated by the military departments. Unable to remake the bureau in Westinghouse's image, Condon charted a more pragmatic course that betrayed his instincts. He staked the bureau's future on research in select fields that catered directly to the technological requirements of the armed forces.

This compromise—born out of necessity to accommodate the broader shift toward permanent military preparedness—wrecked the cooperative vision of academic and industrial research that Condon had carefully nurtured. It also undermined the stability of his career, a theme that is discussed in the concluding chapter. Condon did not pull punches, especially when he judged someone to be misguided or wrong. He had already acquired a reputation for impetuous and combative behavior. These personality traits and a commitment to progressive-left politics clashed with the rising tide of anticommunism after the war. No longer interested in public service under such conditions, he resigned from the Bureau of Standards in 1951. The political fallout and ongoing harassment from the Un-American Activities Committee in the House of Representatives (HUAC) cut short his brief tenure as director of research at the Corning Glass Works in 1954 and precluded a seamless return to the academy. He finally obtained a permanent position at Washington University in St. Louis in 1956, but the appointment marked a steady withdrawal from active research and brought to a close a long career in industry and government. Thirty years earlier, Condon had set out to pursue an abiding interest in industrial research that nearly a decade on the leading edge of theoretical physics at Princeton did not diminish. To the contrary, by way of his introduction to quantum mechanics in the 1920s, Condon glimpsed for the first time the practical bent that structured his scientific outlook and career ambitions.