Research and Development in the United States since 1900:
An Interpretive History

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Economic History Workshop
Yale University
November 11, 2013

Note to Readers: This paper is a bit unorthodox in scope and format. It will eventually appear as an extended entry in the *Oxford Encyclopedia of the History of Technology in the United States*, an editorial project currently occupying much of my time. Although the essay is drawn substantially from secondary sources and from readily accessible government data, I believe it offers some novel points of interpretation and emphasis. I look forward to your input.

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The phrase "Research and Development" entered the American lexicon at the dawn of the twentieth century, when a handful of prominent business institutions announced the creation of research laboratories. Employing small staffs of college-trained scientists and engineers, including some with the doctoral degree, these early corporate research facilities typically focused on pressing technical problems of vital importance to the enterprise. At Kodak, for instance, chemists sought to navigate the transition from glass plate negatives to celluloid film. General Electric Corporation (GE), concerned its highly profitable patents for incandescent light bulbs would soon expire, looked for experts in materials science to develop new filaments. American Telephone & Telegraph (AT&T) hired experts with similar knowledge in an effort to develop a repeater that would boost signals and enable the firm to fulfill its promise of providing coast-to-coast service. Chemical giant DuPont, which had built its empire primarily by manufacturing gunpowder, hoped to broaden its product line by mastering techniques of organic chemistry. In taking this step, DuPont mimicked German chemical firms, whose research laboratories had brought them to positions of international leadership in fields such as nitrocellulose explosives (dynamite) and synthetic dyes.

This spurt of institutional developments was facilitated by shifting legal doctrines. Courts first clarified that corporations could require in-house inventors to assign patents to the firm as a condition of employment. While these rulings gave corporations confidence they could retain control over technologies developed internally, increasing antitrust activity made some large firms leery of acquiring new technology through merger or cross-licensing with other corporations. Firms faced with antitrust suits also looked to curry public favor by touting their investment in research and development.   By achieving technical breakthroughs such as improved light bulbs and accomplishing watersheds such as cross-country telephone service, firms such as GE and AT&T countered notions that large firms suppressed invention and creativity. Public relations experts, who became much more prominent in corporate America during the opening decades of the twentieth century, often seized upon the new laboratories as valuable assets in their campaigns to stem the tide of government regulation.

For all their prominence, these conspicuous pioneers can hardly be said to have constituted a revolution in American technology and invention. The new ventures were restricted to a few firms in a handful of sectors. In 1919, industrial labs employed fewer than 3,000 scientists total, even though AT&T and GE employed several hundred between them. The pioneering R&D labs were also highly concentrated in the Middle Atlantic region, where large corporations had ready access to Wall Street financing and an established university system. Most business firms in other parts of the country, and many in the eastern seaboard, continued to obtain new technologies through loose networks of independent inventors and small proprietors such as machine works. Such networks or regional clusters often included firms that maintained close ties to inventors or were founded by inventors themselves. Often, such clusters focused on niches. Cleveland entrepreneurs designed machine tools and electrical apparatus. A group of foundries and machine shops clustered in an industrial district south of downtown Los Angeles specialized in designing pumps and other implements for use in the region’s booming agricultural and petroleum sectors. It later proved instrumental in supporting the aviation industry, whose pioneers had migrated to Southern California to take advantage of the nearly ideal conditions for testing aircraft.

Nineteenth-Century Roots

As the existence and persistence of industrial clusters suggests, the activities that came to be labeled “Research and Development” long anteceded the creation of formal facilities with that designation. Considerable learning occurred independently of the search for novelties. Most manufacturing enterprises, for instance, continually sought to improve processes and drive down the costs of production. Such learning occurred almost routinely. Often, it involved close collaboration between designers of new products and the technicians tasked with mastering their production. The interplay between them constituted what would later be called the development process. Similarly, designers often coordinated their efforts with operators of the larger technical systems into which their inventions must be integrated. This might take place within a single establishment, as when a manufacturer looked to enhance a production line or a railroad or utility company sought to refine the performance of its facilities. Or it might involve cooperating with customers through teams of sale representatives and field engineers, who helped purchasers to master new products while also serving as the eyes and ears of their employers, collecting information about how they might enhance product offerings and gathering valuable information about competitors. All of this activity generated new knowledge vital to the health of the firm, long before anyone thought to brand it research and development. Such activity would long remain an essential source of learning throughout the economy, even in sectors where firms created distinct research laboratories.

By the end of the nineteenth century, some large firms had taken steps to formalize this sort of learning and render it more routine. Many of the nation’s largest railroads, for instance, established staff offices that monitored learning and innovation throughout their vast systems. These efforts often included departments of testing and research, where college-trained engineers and chemists evaluated existing technologies and assessed potential alternatives. Much of this work focused on materials science, such as the behaviors of metals and lubricants, but it also involved systematic study of appliances that might enhance fuel economy or the traction of locomotives. The giant Pennsylvania Railroad, which in 1876 had become the first American corporation to hire a Ph.D. chemist, early in the twentieth century erected a facility for testing locomotives in place while operating at speeds as high as ninety miles an hour. In conjunction with its effort to tunnel beneath the Hudson River and enter Manhattan in 1910, the Pennsylvania also built an extensive test track along the Delaware River for conducting studies of electric traction.

This sort of testing-centered research took hold in many sectors of the economy. Many manufacturers implemented similar programs of materials analysis, often with testing equipment similar to that used by the railroads. The Arthur D. Little Company of Boston provided chemical analyses to numerous firms who could not afford to operate their own testing laboratories. Firms in many industries also followed the Pennsylvania in erecting large-scale testing plants where engineers could systematically evaluate prototypes. Electrical manufacturers such as GE and Westinghouse, for instance, used such prototyping facilities to test electric generating and distribution technologies. Based on knowledge gleaned from such analysis, the electrical suppliers could then assess the efficiencies of proposed installations in the field. In the 1890s, GE placed responsibilities for this function in a Calculating Department under supervision of esteemed mathematician Charles Steinmetz. (It was Steinmetz who later helped persuade GE management to hire Ph.D. metallurgists in its efforts to design a better light bulb.) AT&T similarly formed a calculating department in order to evaluate the efficiency of proposed telephone exchanges. Using novel statistical analyses, mathematicians in this department grew to understand how various components influenced overall performance of telephone systems. This capability gave AT&T a powerful tool in assessing emergent technologies and establishing standards of performance, functions which were just as integral to the later success of its famed Bell Laboratories as the knowledge generated in trying to build a better repeater and achieve long distance.

In fostering a more systematic approach to evaluating new technology, the nascent laboratories put corporations in a better position to sift through the vast output of the many specialized independent inventors who emerged in the late nineteenth century, as a national market for patented technologies took shape. Conspicuous figures such as Thomas Edison and Elihu Thomson churned out hundreds of patents from their own “invention factories,” as Edison dubbed his facilities at Menlo Park, New Jersey. Hundreds of others generated more modest portfolios. Personnel in the corporate labs monitored the sea of developments, often with the aid of specialized patent attorneys, identifying those of particular worth and spotting areas where they might direct their own talents and resources. AT&T acquired rights to its vacuum tube repeater, critical to achieving long distance transmission, from the independent inventor Lee de Forest. The electrical giants Westinghouse and GE assembled large portfolios of patents (in GE’s case by employing the prolific Thomson) and used them to form a pooling agreement that kept competitors at bay.

In addition to these developments in private industry, a variety of public institutions emerged during the late nineteenth and early twentieth century to support learning and innovation. One important complex of institutions organized around agricultural activities, which constituted the largest sector of the American economy through most of the nineteenth century. Early on, much of this research activity took place through forums such as state and county fairs. In the 1850s, farm interests pushed through legislation compelling the U.S. Patent Office to conduct ongoing examinations of agricultural techniques, including soil enhancements, new varieties of plants and animals, and remedies for insects and other pests. This program was later institutionalized with formation of the United States Department of Agriculture in 1862. The USDA often conducted its research and disseminated the resulting knowledge in collaboration with state agricultural universities, funded under the 1862 Morrill Act, and their associated agricultural experiment stations. This federalist approach generated a common body of knowledge, often grounded in the techniques of laboratory science, while remaining highly attuned to local conditions and actual practices. In combining laboratory studies with test farms, it exhibited some of the same features that characterized developments in the private railroad industry.

A similar constellation of research efforts emerged in connection with mining, another vital sector of an economy whose wealth derived largely from the land. Here, too, a nexus of state and federal institutions supplied systematic laboratory analyses and field explorations, such as those conducted by the U.S. Geological Survey and the Bureau of Mines, while also gathering and codifying knowledge gleaned from numerous specific locales. Many land grant universities built programs of education, research, and outreach in fields such as geology and mining engineering. Like engineers in other fields, the mining professionals formed organizations that conducted meetings and published journals that served as clearinghouses for new knowledge and techniques. Often tailored to the resources of particular states and regions, such activities undergirded the spectacular achievements in the mining of precious metals and of fossil fuels such as coal and petroleum, which constituted a major share of American exports and provided American manufacturers with their competitive advantage in global markets.

In addition to supporting research for agriculture and mining, the federal government also conducted research through institutions such as the Coastal Survey, the Weather Bureau, and the National Bureau of Standards. Created in 1900, the latter became an important forum for establishing norms of scientific research, including calibrations of new instruments. Its role in facilitating collaboration and exchange among investigators grew increasingly important as the number of laboratories proliferated across government, universities, and the private sector. The Bureau also established a precedent for more targeted efforts at technical standard-setting, such as those conducted by the Federal Radio Commission following its formation in 1912.

World War I and the Interwar Period

By the time of American entry into WWI, then, the United States possessed an impressive array of institutions and practices aimed at generating technical innovation and gaining more sophisticated and systematic understanding of technologies. As that war approached, President Woodrow Wilson actively looked to tap those capabilities. In 1915, while still maintaining a policy of neutrality, his administration organized a Naval Consulting Board. Headed by Thomas Edison, it pursued research of relevance to the U.S. Navy. At the urging of George Ellery Hale, foreign secretary of the National Academy of Sciences, Wilson subsequently created a National Research Council, whose members included John Carty of AT&T and other scientists with links to industry. Suspending his suspicion of big business and enthusiasm for antitrust, Wilson later cleared the way for firms such as GE, AT&T, and Westinghouse to focus their collective research capabilities on critical areas such as sonar and wireless telegraphy (radio), while firms such as DuPont turned their attentions to synthetic products such as fuels, fertilizers, fabrics, and poison gas, and Henry Ford's auto plants built specialized boats and trucks for the military.

These conspicuous wartime efforts, which appeared vital to national purpose, drew the corporate research laboratories more fully into the limelight and tied them more firmly in the public's mind with the generation of new products. The association grew all the more prominent in the early twenties, as many of these same firms produced a stunning array of novel consumer goods. Work on sonar and radio sparked a revolution in sound, with broadcast radio, electrical recording, amplified loudspeakers, and talking pictures all sweeping the nation in a matter of a few years. GE introduced mechanical refrigeration, while DuPont and General Motors combined to civilize and urbanize the automobile by adding innovations such as electric starters, bright lacquer finishes, chrome highlights, antifreeze to permit winter operation, and tetraethyl gasoline additives to reduce engine knocking.

These startling accomplishments secured a firm place for corporate laboratories and organized research and development in American industry. Between 1919 and 1936, U.S. manufacturing firms established over a thousand industrial research laboratories, roughly half of the total number of such facilities founded prior to 1946. New labs cropped up in industries such as autos, metals, petroleum, and pharmaceuticals, while those of electrical and chemical pioneers grew markedly. The number of scientists employed in research laboratories increased tenfold between 1920 and 1940, from 2,775 to 27,777. Typically, at least half of them worked in the largest ten percent of the labs, as big firms across the economy came to see research as essential. Investors took note. Over the course of the twenties, stock values came to reflect an assessment of a firm's potential to generate new technologies and accumulated expertise in research, rather than merely its physical assets.

While developments in the private sector flourished, WWI did not produce a corresponding watershed in government policy regarding research. President Wilson and his advisor George Ellery Hale, President of the National Academy of Science, failed in their efforts to secure a permanent federal agency for funding scientific research. Hale ultimately retreated to California and the presidency of what would soon be renamed the California Institute of Technology. Academic institutions such as Caltech and MIT grew dramatically during the twenties, while older liberal arts institutions such as the Ivies and the University of Chicago built new capabilities in the sciences. Much of the funding for these transitions came from private philanthropic organizations such as the Rockefeller Foundation and the Carnegie Foundation, which in addition to supporting the construction of new research facilities on college campuses, opened its own facilities in Washington, D.C. Another foundation, named for Solomon Guggenheim, funneled resources toward the emerging field of aviation by financing the construction of wind tunnels on numerous college campuses. These experimental facilities, crucial for the testing of airfoils and other prototypes, essentially seeded the creation of aeronautical engineering as an academic discipline across the nation.

Although much of this largess flowed to private institutions, public colleges and universities garnered some of the spoils, while also expanding their research stations. The most dramatic growth occurred where stations established closer ties with regional business interests. Engineers and scientists at the University of Michigan, for instance, generated significant research funds by servicing the needs of the booming automobile industry. The University of California provided analyses for the state's hydroelectric and petroleum industries. Scientists at the University of Georgia developed techniques for making paper from the state's vast pine wood forests and for raising poultry on an industrial scale. Such examples gently nudged public universities toward broader research missions and away from a narrower focus on teaching that many faculty and taxpayers preferred.

Despite its devastating economic effects, the Great Depression did not fundamentally alter the structure and direction of American research and development. The number of scientists and engineers employed in American industry actually increased over the course of the depression decade. Some evidence indicates firms considered research a comparatively inexpensive investment, since it involved personnel rather than facilities. In many instances, moreover, research might yield economies by pointing to efficiencies, much as it had at institutions such as the Pennsylvania Railroad and AT&T, where the vaunted Bell Laboratories organized much of their efforts toward the objective of lowering the cost of phone service, rather than introducing novelties. In at least some instances, however, firms appear to have spent with an eye toward invention. Visitors to the 1939 World's Fair in New York encountered a World of Tomorrow, made possible by corporate research. RCA and Westinghouse introduced television at the fair. DuPont launched its "Better Things for Better Living through Chemistry" campaign and announced a remarkable new synthetic fiber, Nylon, which could substitute for silk stockings. Consumers lined up outside Manhattan department stores to attain a pair.

World War II

By the time the World of Tomorrow closed its gates on October 31, 1939, war had erupted across Europe. Although United States troops would not join the combat for more than another two years, the war soon began transforming the structure of American research and development. As the Nazi threat mounted, President Franklin Roosevelt searched for ways to lend support to Allied resistance. With Congress reluctant to commit resources for troops or arms, FDR turned to engineers and scientists engaged in research, whose modest needs he could support without special budget authorization. In June 1940, the President tapped Vannevar Bush to head the new National Defense Research Committee (NDRC), which FDR had created by executive order.

Bush was a prime exemplar of a new breed of science and engineering ambassador who had learned to cultivate favor in the nation's capital. A former dean of engineering at MIT, Bush had relocated to Washington in 1939 to head the Carnegie Institution. By the time he joined NDRC, he had secured appointments on the President's Science Advisory Board and on the advisory committee of the National Advisory Committee on Aeronautics, while also chairing the National Research Council's division of engineering and industrial research. Bush attained the latter post at the recommendation of Frank Jewett, director of AT&T's Bell Labs, who served as president of the National Academy of Science, which oversaw the NRC. Jewett joined Bush on the NRDC, as did MIT president and physicist Karl Compton and Harvard president James Conant, a chemist. Representatives of the War and Navy departments also held posts on the committee, along with an expert on patents and a general assistant.

Over the course of the war, NDRC and its subsidiary Office of Scientific Research and Development (OSRD), which was created in May 1941 in order to give Bush access to Congressional budget allocations, distributed nearly half a billion dollars to research and development projects aimed at generating new weapons. All told, OSRD entered into over 2,300 research contracts and distributed funds to some 321 industrial companies and another 142 academic institutions and other non-profits. Whether aimed at academics or industry, OSRD funds went overwhelmingly to institutions with established research capabilities. This meant most of the money flowed to a handful of states in New England and the Mid-Atlantic, plus

California. Together, MIT and Caltech received more than $200 million in contracts, or roughly forty percent of all allocations. MIT housed the sprawling Radiation Laboratory or “Rad Lab,” which conducted much of the nation’s research and development on radar technology. Caltech conducted research on aeronautics, including development of the proximity fuse, a detonation technique developed by Merle Tuve that many military historians consider vital in swinging the war of the air toward the Allies. Harvard and Columbia were next in line, with roughly $30 million apiece, while the University of California claimed just under $15 million. From there, allocations fell steadily. The University of Pennsylvania ranked tenth among academic institutions with slightly more than $3M. Allocations to private business exhibited a similar tendency to reward the privileged. Western Electric, the manufacturing arm of AT&T, topped the list with more than $16M in OSRD funds. Next came GE, which received $8 million, followed by RCA, DuPont, and Westinghouse, each with allocations between $5 and $6 million. Standard Oil, the tenth-ranked industrial recipient, claimed about the same amount as the University of Pennsylvania.

While only a few institutions grew rich through OSRD contracts, many others tasted for the first time the fruits of federal largess. Literally hundreds of small and mid-sized firms were drawn into its orbit, often through sub-contracts from major players such as MIT and Caltech. Even a small contract could make a strong impression on a business or a campus that had not previously conducted sponsored research, and leave administrators and faculty longing for more. In this way, OSRD helped foster a transformation in thinking about the research enterprise whose effects would extend long after the war.

That transformation was hastened, and perhaps ultimately overwhelmed, by wartime research and development programs funded by other branches of the federal government.

Established research efforts conducted by the Department of Agriculture, the Bureau of Standards, and NACA all grew significantly during the war. Together their budgets rivaled that of OSRD. By far the most important investments, however, flowed from the War and Navy Departments themselves. The former expended more than $800 million on research and development between 1940 and 1944, during which OSRD expenditures totaled just $350 million, while the Navy spent another $400 million. Whereas nearly two-thirds of OSRD allocations went to academic institutions and non-profits, funding from the military departments went overwhelmingly to private industry and to facilities operated by government. Together, the two departments pumped nearly $800 million of research and development funds into private industry during these years, while also laying the foundation for government institutions such as the Naval Research Lab (NRL). Much of this funding from the War Department, moreover, went toward emergent fields such as aviation (via the Air Corps), electronics (via the Signal Corp), advanced calculation (via the Ordnance Department), and nuclear technology (also via the Ordnance Department).

No single wartime R&D program, of course, exerted a more profound impact than the Manhattan Project and its atomic bombs. The bomb project touched many of the institutions discussed earlier in this section. Bush and his OSRD colleagues showed little enthusiasm for the idea when they first learned of it in early 1940, when radar and the proximity fuse held more immediate promise of fending off the Nazis. But when British scientists shared ideas about a bomb based on the rare U-235 isotope, Bush and Conant joined a select committee to oversee the project. The tasks of obtaining and mastering U-235 occupied theoretical and empirical investigators from across the physical sciences. The effort drew upon academics from the nation’s leading institutions, including Chicago, Columbia, Harvard, Caltech, and Berkeley, while also mobilizing industrial chemists and plant builders from firms such as DuPont, GE, and Eastman Kodak. The War Department eventually took control of managing the project, although even researchers from the NRL managed to get involved, after they proposed a potential means of obtaining the vital element. This eclectic assemblage focused its efforts on a project of overwhelming military significance, one which not only brought the war against Japan to an abrupt end, but also opened a field of scientific and technical endeavor that would forever hold the fate of the world in the balance. The specter would do much to shape the course of U.S. R&D in the decades to come.

Postwar Research and the Linear Model

More than a year before Hiroshima and Nagasaki, Vannevar Bush had begun laying the groundwork for federal support of postwar science and technology. With the encouragement of FDR, he drafted a letter and accompanying public speech that attempted to preserve a role for the federal government in research and development even in peacetime. Concerned that the war effort had drawn academic scientists deeply into military projects and left the stocks of new knowledge depleted, Bush looked to fund these scientists, while also providing them a degree of autonomy. His idea was to create a federal agency whose allocations to science would be governed by peer review, without undue influence by politicians or the military. To drum up support for this vision, Bush began giving a public lecture that came to be known by the title "Science – The Endless Frontier." Sounding not unlike exhibit narrators from the 1939 World's Fair, Bush spoke of a prosperous, safe, and healthy future made possible by science, whose frontiers (unlike the geographic frontier of the West) knew no bounds. Anxious to distance science from the destructiveness of war, Bush laid particular emphasis on developments such as penicillin and chemical insecticides, which had saved many lives by limiting the effects of disease. Elsewhere, Bush also described the potential of innovations in information science and technology to revolutionize all knowledge-based activities. His proposed Memex machine imagined desk workers gaining access to entire libraries and sending documents and images electronically – a vision that foreshadowed the Age of the Internet, long before its time.

The visions Bush promulgated grew from his wartime experience, yet in crucial respects seemed at odds with the lessons of wartime research and development. Environments such as the Rad Lab, the Manhattan Project, and the Aberdeen Proving Grounds (where a team of researchers from the University of Pennsylvania conducted pioneering experiments in digital calculation) had demonstrated how innovation could develop in spectacular fashion when scientists from the academy interacted with industrial scientists and engineers on projects aimed toward concrete ends. Although these military environments had sometimes been plagued by secrecy and resentments, in many cases the interaction had proved quite fruitful, generating not only new technologies, but new knowledge as well. Now, Bush appeared to advocate a re-separation of the parties and the establishment of a new division of labor, in which academic researchers generated "basic" knowledge that diffused to more practically-oriented teams in industry and the military, who would develop applications. The vision came to be known as the linear model of innovation.

Perhaps not surprisingly, the vision was a difficult sell. Military leaders, having grown to appreciate the importance of science and innovation to their endeavors, did not welcome the idea of letting scientists retreat to the Ivory Tower. Nor did many younger scientists, who had survived the doldrums of the Great Depression and enjoyed the intellectual excitement and material rewards of the wartime projects, rush to embrace the vision of an idyllic academic independence they had never known. Further resistance came from politicians in Congress, including conservative Republicans and many Southern Democratic associates of President Harry Truman. In 1947, Truman vetoed an early version of a bill creating a national science foundation. Truman and his cohort hesitated to cede control over a significant budget line to scientists, who would then decide where and how to allocate it. Such politicians wondered how the public could insure such funds ultimately went toward socially beneficial purposes, including those in their home states, many of which had received little from OSRD. They grew especially uneasy when Bush insisted that any patents resulting from such research should be retained by those receiving funding, including industrial partners, rather than be held by the public. This suggestion ran directly counter to efforts being pursued by antitrust lawyers in the U. S. Department of Justice to compel large corporate laboratories, many of which had received significant contracts from government during the war, to license all patents for a reasonable fee. Meanwhile, business leaders such as Jewett of Bell Labs criticized Bush for putting science on the public dole, a complaint echoed apparently without irony by Caltech President Robert Millikan, whose institution had collected nearly $100M from OSRD. Evidently, Millikan preferred a system in which a small group of government science administrators granted contracts to premiere institutions with close ties to industry, rather than one which allocated funds through a competitive process of peer review conducted by academic scientists.

Resistance from these many quarters delayed passage of a bill establishing the National Science Foundation (NSF) until 1950. Although this bill largely fulfilled Bush’s vision, intervening events had essentially overwhelmed the initiative. While the bill languished, other branches of the government pumped roughly a billion dollars a year into research and development. Much of this came from the Department of Defense (DOD), an umbrella organization encompassing Army, Navy and the newly created Air Force. Each branch had its own agenda and budget for research. Additional expenditures came from the Atomic Energy Commission (AEC), which supported both military and civilian uses of nuclear technology. In 1950, when NSF eked out a measly $350,000 budget authorization (against its mandated cap of $15 million), these agencies and the Public Health Service together pumped some $63 million in R&D funding into academic and non-profit institutions. Even those authorizations, moreover, paled in comparison to what the various units of DOD and the AEC poured into their own government laboratories and subcontracted to industry. Government expenditures had thus continued to follow wartime patterns, with funds allocated to institutions under administered contracts rather than through processes of academic peer review.

While government expenditures held steady at their newly established levels, private investment in research and development grew markedly during the late 1940s. In 1946, such investments stood at roughly half a billion dollars, essentially half the public expenditures for that year and about the same as private investment five years before, at the start of the war. By 1951, private investment had increased nearly fourfold, to nearly $2 billion, half again as much as the public sector spent that year. Perhaps not coincidentally, these were years of spectacular commercial innovation, as television rapidly displaced movies, nylon and other synthetics swept through the fashion trade, air travel replaced long-distance railroading as the jet age dawned, AT&T announced the transistor, and election results were projected and compiled by “electronic brains” built by Sperry-Rand and IBM. The endless frontier appeared to have become reality, without public investment in peer-reviewed academic research of the sort Bush advocated.

These transformative innovations had not, of course, simply sprung to life since the war. All were the products of longstanding research and development efforts with roots deep into the depression decade, or even earlier. This was true even of the electronic computers; IBM and others had experimented with electronic calculation during the thirties, and users had looked for ways to adapt existing equipment to perform complex calculations more rapidly. Nor were these innovations merely the products of research and development conducted by a single corporation. Even the transistor, which generated enormous buzz and quickly earned its three creators the Nobel Prize, drew on a body of learning in the physical sciences that transcended Bell Labs. The airline industry rode on a wide base of research, much of it conducted through construction and testing of prototypes, many of which were built for military purposes. The televisions sold by RCA and Westinghouse after the war were far superior to prewar sets, yet cheaper, because they benefitted from research on tubes and other electronic components conducted at the Rad Lab.

Indeed, virtually all of the commercial successes of the postwar decade owed a great deal to the wartime experience. Some were influenced by targeted research projects such as those sponsored by OSRD. In many cases, however, primary support came from wartime procurement. IBM’s established accounting business tripled during the war. Demand for long-distance telephone service mushroomed. Aircraft production reached unimaginable heights. Exploding demand pumped resources into private firms, often enabling them to build new factories and other facilities. Beyond the capital expenditures, the wartime boom often sparked extensive learning across the workforce, as companies scrambled to meet production goals under trying conditions. Managers looked for ways to move products into manufacturing environments more smoothly, to pursue sustained improvements across a learning curve, and to support new technologies in the field, where they might undergo further refinement. Much as conditions at the Rad Lab and Manhattan Project broke down barriers between academics and industry and scientists and engineers, firms pursuing wartime production goals fostered unprecedented cooperation, and in the process learned valuable lessons about the nature of innovation.

Many of those wartime experiences and the postwar legacies they bequeathed did not remotely correspond to the linear model. Yet these successes indisputably raised the profile of research across American industry, while also associating it more strongly than ever with large corporations. At the dawn of the Eisenhower Age, many Americans readily presumed that the health of the national economy rested squarely upon investment in corporate research and development, just as the security of the nation now hung on military research and development.

The Military-Industrial-University Complex

A recurrent issue of the Eisenhower years was whether the nation could in fact achieve both prosperity and security, and maintain a proper balance between them. Eisenhower brought the matter into sharp relief with his farewell address of 1961, when he raised concerns about what he characterized as a military-industrial-university complex. “The prospect of domination of the nation’s scholars by Federal employment, project allocations, and the power of money is ever present” Eisenhower cautioned, “and is gravely to be regarded.” Pondering automobile designs whose tailfins resembled those on rockets, the departing President later spoke of “almost an insidious penetration of our minds that the only thing this country is engaged in is weaponry and missiles.”

Eisenhower’s comments reflected his deep frustration with trying to control costs on the military side of the ledger. As he entered the White House, the defense budget had jumped precipitously, as the nation reeled under the simultaneous burdens of trying to fight a land war in Korea while also responding to the Soviet nuclear threat. The effects were evident in the federal research and development budget, which had jumped from $1.3 billion in 1951 to $3.1 billion in 1953. Virtually all of the increase was tied to defense, as President Truman authorized major projects such as the thermonuclear or hydrogen bomb and a sprawling computerized anti-aircraft defense system known as SAGE. In 1953, nine out of every ten dollars the federal government spent on research and development went to defense. The surge in defense-related research was all the more striking because it was accompanied by a flattening of private expenditures. In 1953, government accounted for 54% of the nation's R&D funding.

Eisenhower was by no means opposed to R&D. He considered such activities and the technologies they produced an affordable alternative to deploying large conventional armed forces across the globe. But Eisenhower looked for R&D to generate "dual-purpose" technologies, such as communications satellites, nuclear power plants, and digital computers, that served both civilian and defense needs. In his mind, such technologies might come as readily from private civilian research as from federal dollars targeted expressly for defense. He looked for private R&D investment to provide both prosperity and security.

Total R&D investment did, in fact, grow dramatically during Eisenhower's eight years in the White House. In 1953, the $5.2 billion investment had amounted to 1.36% of the U.S. Gross National Product (GNP). The $13.7 billion invested in 1960 constituted 2.60% of GNP. This near doubling of the proportion of economic activity going to R&D marked an enduring change. In the years hence, the percentage has never dropped below 2.12 and never surpassed 2.88, a level reached in 1964 and 2009. Over the course of that period, the annual expenditure has averaged almost exactly the 1960 level of 2.60% of GNP.

Contrary to Eisenhower's hopes, this leap forward in the nation's research capacity was fueled overwhelmingly by the federal government. The federal share of research spending grew from 54% in 1953 to 65% in 1960. The federal investment, moreover, remained heavily skewed toward defense. Of the $9 billion the federal government spent on R&D in 1960, eight of every ten dollars were targeted directly for military endeavors. Another seventy cents of each ten dollars went to the space program, ostensibly a civilian endeavor, but one with strong ties to the military and driven by Cold War objectives.

The massive federal investment in R&D during the Eisenhower years overwhelmed growth in spending by private industry and other sources. Although funding for R&D from non-federal sources increased by some 75% in constant dollars from 1953 to 1960, and the ratio of such funding to GNP grew from 0.63% to 0.91%, these figures paled when compared to the 178% increase in federal funding and the associated growth in share of GNP from 0.73% to 1.69%. Federal dollars flowed so liberally during the fifties that they came to constitute the largest source of support even for R&D conducted by private business. In 1953, federal funding had paid for less than forty percent of R&D carried out at industrial facilities. By 1957, the federal share had soared to 56 percent. It peaked at 59% two years later and would not drop below 54% until 1967. When Eisenhower left the White House, federal expenditures at corporate R&D facilities were 3.7 times what they had been at the start of his presidency, an increase of 270% even after adjusting for inflation. The 75% increase in corporate expenditures at their R&D facilities appeared rather paltry by comparison. Figures such as these go a long way toward explaining why these years are often referred to as the Golden Age of corporate research, and why Eisenhower voiced concerns about a military-industrial complex.

Why Eisenhower also implicated universities may at first glance appear more puzzling. Of the $13.7 billion invested by all sources in R&D in 1960, only about $1.1 billion (8%) went to universities and colleges, including about $385 million earmarked for federally funded centers such as nuclear laboratories run by the University of California. All told, the federal government allocated just $838 million (or 9.5%) of its R&D expenditures to universities and colleges. On a proportional basis, these figures were almost identical to those of 1953. Universities had kept pace and ridden the overall boom in R&D to new levels of activity, but they had not experienced the dramatic shifts in funding sources that had characterized industrial R&D.

What prompted Eisenhower to mention universities was not so much their overall magnitude, as their role. Federal classifications divided R&D expenditures and activities into three categories: basic research, applied research, and development. The distinctions, which in reality were not always easy to draw, corresponded to Vannevar Bush's linear model. In 1953, basic research accounted for just $460 million (9%) of the $5.1 billion total, while applied garnered 25% and development 66%. More than half of the funding for basic research came from the federal government, and nearly half of such research was conducted at universities and colleges. In 1960, these figures stood at $1.3B (9%) for basic, 23% for applied, and 68% for development. More than half of the funds for basic research came from the federal government, and more than half of such research was conducted at universities and colleges. In both years, universities and colleges accounted for only a small fraction of development, which was concentrated overwhelming at industrial facilities (although paid for increasingly by the federal government). Applied research fit a profile similar to development, but less extreme. Universities and colleges conducted applied research, but far less than that conducted by industry, and although the amount of applied research increased over the decade, the university role skewed increasingly toward basic research. Universities were putting less of their own funds into applied research and virtually none into development, but had by 1960 begun to invest significant amounts of their own resources into basic research.

By 1960, then, one could detect a division of labor in R&D, with the federal government spending modest amounts of money for basic research at universities and colleges and large sums for development at industrial facilities. Industry invested about half as much as government in basic research, conducted at its own corporate laboratories, and pitched in about forty percent of the funding for development work, which was conducted overwhelmingly at its facilities. Applied research occupied a middle ground. Funding levels for it fell closer to basic research than to development, and the federal government and industry shared responsibility for both funding and conducting the activity, although universities also participated.

Trends in Federal Support since 1960

Data collected by the National Science Foundation reveals several significant trends in U.S. R&D since Eisenhower left the White House. During the subsequent five decades, total R&D expenditures oscillated from a high of 2.88% of GNP, a level reached during the mid-to-late sixties at the height of the Apollo program and matched with the economic stimulus of 2009, and a low of 2.12% of GNP in1978 at the depths of a prolonged economic malaise.

While overall funding levels remained within that band, the sources of funding shifted dramatically, with the private sector assuming a much larger role. Federal funds still accounted for about two-thirds of R&D through 1968, on the eve of the moon landing, but then fell precipitously over the next decade. By 1978, federal expenditures stood at just 1.06% of GNP, exactly matching the contribution from non-federal (primarily private) sources, which had essentially held steady as a percent of GNP since 1968. Federal funding spiked upward during the Reagan defense buildup of the early 1980s, but funding from private sources increased even more rapidly, as corporations responded to government incentives offering tax credits for funds spent on R&D. By 1985, when total R&D investments stabilized at about 2.7% of GNP, non-federal sources accounted for 54% of the national total. From there, the federal share dropped steadily to a low of just 25% in 2000. Enhanced spending on national security and economic stimulus packages over the next decade pushed the federal share back up to 31% -- precisely half the investment in R&D by private industry in 2009, and less than half the federal share of the fifties and sixties.

This inversion of funding sources was accompanied by significant shifts in the types of activities supported by federal and private dollars. Overall, the nation's R&D efforts remained heavily skewed toward development. In 2000, development still accounted for 62% of total R&D expenditures, just six percentage points less than in 1968. (Applied research oscillated between 18-23%, while basic research grew from ten to sixteen percent.) Throughout the period, development consistently accounted for 75% or more of R&D activities conducted at industrial firms. What changed was the source of funding. Essentially, the federal government diverted more funds toward basic research conducted at universities and other non-profits, while drastically reducing its expenditures on development at private industrial facilities. In 1968, the federal government still covered more than half the cost of industrial development. By 1980, industry had assumed two-thirds of such expenses, and by 2000 it paid for more than 90% of its development costs. At that point, only about one-quarter of federal R&D expenditures went to industry, and federal funds amounted to just 8.6% of industrial R&D budgets. (These numbers do not reflect tax credits, which indirectly subsidized industrial R&D).

While direct federal investments in development dropped, the share of federal R&D expenditures devoted to basic research rose from 16% in 1968 to 38% in 2004. Those investments, moreover, were increasingly concentrated at universities and other non-profits. The share of federal research dollars captured by such institutions, which already stood at 64% in 1968, grew to more than 80% in 2004. Such institutions also doubled their share of federal funds devoted to applied research, which comprised roughly a fifth of the federal R&D budget. By 2004, about a third of those funds went to universities and other non-profits. All told, by 2004 roughly a third of all federally funded R&D went to basic and applied research conducted at universities and other non-profits. Another fifteen percent of federal expenditures went to development activities at government laboratories and other non-profits.

Even with these dramatic shifts federal priorities, the precipitous drop in overall federal investment in R&D relative to GNP would have led to reduced funding for basic and applied research if not for infusions from non-federal sources. Over the course of the 1990s, the share of funding for basic research provided by industry actually grew from 10% to 25% of the national total, even though basic research accounted for just 5-7% of total R&D expenditures by industry. Private funds accounted for 20% of national funding for basic research even after large infusions of federal funds during the opening decade of the new millennium. Most of those private funds went to basic research conducted at industrial facilities, but some 15-25% found their way to universities and other non-profits, so that by 2000 about five percent of university research budgets came from industry. Additional funding for research at universities flowed from the universities themselves. Such internal funds constituted more than 20% of university research budgets in 2000, twice their share in 1968. State and local governments and other non-profits together kicked in another 15% of university research budgets. Taken altogether, these non-federal sources accounted for about 40% of university research – a far larger proportion than in 1968, even with the federal government making such a priority of university research in its own budget. Such investments help account for why the ratio of dollars spent on development to those spent on basic research fell from nearly 7-to-1 in 1968 to slightly less than 4-to-1 in 2000.

The shifting patterns of research expenditures and activities in large part reflected changes in the areas of investigation, which in turn reflected shifting national priorities and changes in the nature of economic activity. During the Kennedy and Johnson administrations, when public funds paid for most R&D, the emphasis remained overwhelmingly on defense and space technology. Together, they accounted for 85% of the federal R&D budget in 1964, with the remaining 15% scattered among other fields of endeavor.   The heavy emphasis on weapons systems and manned space exploration, areas involving highly complex technical infrastructure, skewed federal R&D expenditures toward the development side of the ledger.

The balance swung toward basic research during subsequent administrations partly as a consequence of increased federal emphasis on medicine and health. Federal R&D support in these areas flowed primarily through the National Institutes of Health (NIH). Its roots went back to the 1930s, when Congress authorized construction of a modest research facility at Bethesda, Maryland. Shortly before World War II, NIH gained responsibility for the National Cancer Institute (NCI), the first of what would eventually become some two dozen institutes focused on specific diseases and disorders. NCI ran a modest grants program, akin to that Vannevar Bush envisioned for NSF, which distributed modest sums to independent researchers at universities and medical facilities. During the latter part of the war, NIH adopted this grants model across the entire agency. Sums remained modest. The entire budget came to less than $3.5 million dollars in 1946, five times prewar levels, but a tiny fraction of what Bush allocated through OSRD or the various branches of the military spent on R&D.

NIH grew dramatically after the war, as it broadened its grants program to include clinical research and founded new institutes focused on areas such as heart and lung disease, diabetes, neurological disorders, allergies and infectious diseases, child development, and mental health. With its budget growing ten-fold by 1953 and a hundred-fold by 1960, NIH claimed a progressively larger share of the rapidly expanding federal pie. When Eisenhower left office, it accounted for 4.5% of federal R&D, and its share climbed to 7.1% during the Kennedy years before plateauing under Johnson. Still, expenditures on medical research lagged far behind the shares commandeered in 1968 by defense (52%) and space (27%).

With curtailment of the space program and the relative decline in public support for R&D, NIH claimed a steadily larger share of a more modest pie. By 1980, its share of federal R&D funding had crept up to nearly12%, on par with the amount expended on energy, the pet cause of the Carter administration. After stabilizing at that level during the Reagan years, when defense again claimed upwards of two-thirds of R&D funding, the share expended on medical-related R&D climbed steadily. By 1992, the NIH budget of $9 billion accounted for more than 15.5% of federal R&D. It then exploded over the next decade, tripling in absolute terms and doubling its share to nearly a third of all federal R&D expenditures, as the Clinton and first Bush II administrations made disease-targeted research a top priority. Their budgets significantly boosted resources for long-established research foci such as cancer, heart disease, and diabetes, while also broadening support for new areas such as AIDS research. After a slow start, funding to address this epidemic reached $1.5 billion in 1995 and grew to double that level over the next decade, where it has remained even as overall spending on NIH plateaued and its share of federal R&D spending slipped back toward 25%.

Unlike areas such as defense, where only a small fraction of R&D expenditures went toward basic research, more than half of the funds expended by NIH were typically classified as basic research. (Although as critics concerned about decreased funding for science often observed, much of this activity occurred in clinical settings rather than laboratories.) In 1980, when health-related research accounted for just 12% of federal R&D, it already claimed more than a third of the federal budget for basic research. From there its share climbed steadily, surpassing fifty percent of basic research in 2000 before leveling off at 56% in the middle of the decade. Together, health and general science (an area funded primarily by NSF) accounted for more than 80% of federally funded basic research that year. Defense and space together amounted to less than 15%; energy had dwindled to virtually nothing.

A large portion of these federal research funds ended up at medical schools and research hospitals, plus associated departments of chemistry and biochemistry. Much of it went toward drug-related research and evaluation. Investment in medical research also accounted for the rising prominence of nonprofit foundations, many of which targeted health issues, as did much of the enhanced funding for research provided by state and local governments and by universities themselves. Academic research in areas such as physics and mathematics literally grew overshadowed by these massive investments in health, as many universities came to resemble vast hospital complexes with quaint adjoining campuses. At the turn into the new millennium, scientists in those fields looked for new federal initiatives in nanotechnology to help adjust the balance.

Federal investment in basic research was accompanied by new policies intended to encourage the commercialization of results. The Bayh-Dole Act of 1980 enabled universities to retain patent rights for innovations resulting from federally-funded research. Although critics blamed the act for promoting secrecy and impeding the free exchange of knowledge, while failing to generate revenue for most universities, legislation prompted vigorous response. Virtually all research universities subsequently invested in offices and ventures devoted to commercialization, and the number of patents taken out by universities increased dramatically. Much of this activity, and most of the few dramatic commercial successes, occurred in health-related research. Investigators in that area found they could readily sell or license rights to biochemical patents to pharmaceutical companies, which used them strategically or incorporated them into drug development efforts, taking responsibility for arduous approval and marketing efforts that researchers would have found too burdensome. Less often, such patents provided the basis for start-up firms developing their own commercial products.

Changes in Industrial Research

Industrial R&D also shifted emphasis over time. In 1969, Cold War technologies still drove most R&D activity conducted by industry. Well over half of expenditures on industrial R&D went to two categories: aircraft (including missiles) and electrical equipment (including telecommunications and components). Machinery claimed another 10%, with likely at least half of that going toward computing, another field with close ties to defense and space. Chemicals and motor vehicles each absorbed another 9-10%. The remaining 15% were sprinkled through a variety of lesser manufacturing industries. This distribution was almost identical to that of 1956, mid-point of the Eisenhower administration.

A decade later, in 1979, the share devoted to aircraft had dropped by a third, to 21%, roughly equal that spent on electric equipment. Machinery ticked up to 12.6%, with two-thirds of that going to computing, while motor vehicles and chemicals showed modest gains to 11.6%

and 10.6%. Besides computing, significant new claimants included scientific instruments, which absorbed 6.6%, and drugs, a subset of chemistry that accounted for 4% of total industrial R&D. The Reagan military buildup, including the Strategic Defense Initiative (Star Wars), skewed efforts back toward aircraft and further boosted computing, while chemicals, motor vehicles, and electrical equipment all slipped modestly.

The drop in electrical equipment in part reflected what would become the most dominant development of the post-Reagan years: the rise of industrial R&D in non-manufacturing sectors, especially services. Much of this initially involved telecommunications services, but increasingly it was driven by computing and software services used in trade and commerce. The share of industrial R&D devoted to such functions escalated steadily from 4% to 10% across the eight years of the Reagan Administration, then exploded to 24.8% during the four years of his successor. This explosion came primarily at the expense of aircraft, whose share was halved during these four years, and from machinery (including computer hardware) and electrical equipment. The only manufacturing sector that drew an increased share of R&D during these years was drugs, which rose comparatively modestly from 4% to 7.5%.

The trend toward services continued, though at a slower pace, in the nineties and into the new millennium. By 2003, 40% of industrial R&D occurred outside of manufacturing. Two-thirds of that went toward trade and professional services, a category that included business computing and science and engineering services. Within manufacturing, aircraft and machinery plummeted to less than 4%, while motor vehicles and chemicals held steady at around 10% apiece. Drug manufacture slipped back to 5%, perhaps reflecting the tendency of pharmaceutical companies to rely on the massive public investment in health-related research at universities. The only manufacturing sector to attract a significantly larger share of R&D resources during these years was electrical equipment, a category which now included the booming manufacturers of computer chips, such as Intel and Motorola.

The shifts in focus of industrial R&D testify to the extent computing technology drove economic and social change in the United States after 1968, especially after 1980, as the world of networked distributed computing and devices took hold and altered procedures and routines in virtually every walk of life. Riding the digital revolution, leading firms in hardware, software, and computer services routinely pumped 10-30% of their escalating revenues into R&D, while new start-ups also entered the field with products and ideas borne of R&D. Even with giants such as IBM, Intel, Microsoft, and Oracle each directing billions of dollars annually toward R&D, smaller firms accounted for a growing share of R&D activity. Prior to the nineteen eighties, firms employing more than 5,000 employees had consistently performed at least 85% of industrial R&D. In 1981, they accounted for 89%, with those employing more than 10,000 responsible for 84%. A decade later, those figures had dropped to 71% and 64%. Nearly 20% of industrial R&D in 1991 was conducted by firms employing fewer than a thousand people. By 1998, firms employing less than 5,000 accounted for a third of industrial R&D, and nearly half of that was done by those with fewer than 500 employees. In 2003, the share performed by firms with 10,000 or more employees stood at just under 55%, nearly thirty percentage points lower than at the start of the nineteen eighties.

The growing prominence of smaller firms reflected the changing nature of technology and markets. During the fifties and sixties, as industrial R&D grew ever more prominent, innovation often occurred through sustained efforts by established corporations to master complex technologies and associated systems. The Big Three automakers worked out the details of nationally distributed mass production of vehicles that underwent perpetual but modest refinement. DuPont leveraged its experience in the manufacture of new synthetic materials. RCA and GE moved from radio to television and fed the new boxes with signals bounced off satellites. AT&T and Bell Laboratories modernized the national phone system, which it monopolized, while IBM morphed its established accounting business into the world of electronic data processing. A handful of aviation pioneers mastered the jet age, while a few others focused on missiles. In many cases, these firms not only dominated their commercial markets; they also focused much of their R&D on government projects, where “the market” often consisted of a single customer, or perhaps a few branches of the armed forces or the bureaucracy. With government often willing to foot much of the bill for development as well as research, such projects were almost irresistible.

In such closed environments, where tasks often demanded that research meld with a wide range of activities necessary to support the system, firms could move with considerable deliberation. A new computer system at IBM, for instance, might evolve over the course of several years with the intent of satisfying the entire market for half a decade or longer. Boeing and McDonald-Douglass pursued aircraft design in similar fashion. DuPont looked to recreate the success of nylon, a product which emerged after a decade of work in synthetic polymers.

By the 1980s, this closed world had begun to show signs of strain. Many industry leaders found themselves losing ground to upstarts, who managed to introduce new products faster and with considerably less investment of resources. As technologies of mass production diffused and grew more commonplace, American manufacturers found themselves competing with imported goods, many of which offered new features. Auto makers lost market share to imported cars of more radical new design, offering better performance, durability, and features at a lower price. Japanese firms beat RCA with a new generation of televisions and accompanying recorders, while the American company squandered resources on the ill-fated Videodisc. AT&T and its vaunted Bell Labs failed to navigate the transition to mobile devices, losing ground to a host of smaller firms (including Nokia, a Finnish manufacturer of rubber boots) whose designs were more attuned to consumer tastes and habits. IBM scrambled to catch up with new entrants who beat Big Blue to market first with solid-state supercomputers aimed at niche markets and later with low-end personal computers built from inexpensive chips. The latter technology opened up vast markets for both custom programming and pre-packaged software, which small firms raced to provide.

In many instances, these developments disassociated product innovation from larger systems of production, testing, sales, and maintenance, effectively lowering the barriers to entry for innovators. Large firms such as IBM re-evaluated their investments in centralized research laboratories, whose celebrated discoveries and numerous patents seldom seemed to lodge in new commercial products. AT&T spun off its famous Bell Laboratories to a subsidiary, which soon foundered in the increasingly competitive environment of digital communications. Management at such giants often downsized the central research facilities and encouraged investigators to license their discoveries to commercial partners, be they within the firm or outside it. Sales and licensing of patents grew increasingly common across the economy, as firms looked to incorporate ideas from numerous sources, whether via trade, through alliances, or by acquiring start-ups. While companies such as Microsoft, Apple, and Google still looked to secure dominant positions through control of integrated technical systems, their ability to do so required that they draw upon a more diverse array of contributors from inside and outside the firm, and their holds often appeared less firm than those once commanded by pioneers in research and development such as AT&T and GE.

Conclusion

Taken together, trends in public and private R&D during the past fifty years indicate one salient characteristic: a marked intensification of commercial concerns. Especially after 1980, R&D was much more likely to be conducted at private facilities and funded by private concerns responding to market stimuli and tax incentives. Rather than serving persistent, long-term strategic objectives such as facilitating nuclear deterrence, exploring space, enhancing telephone service, or securing enduring advantages for dominant firms in sectors such as computing and electric power generation, R&D was increasingly linked to shorter-term aims such as product development and process improvement. In many instances, the primary outputs of R&D were themselves tradeable assets, such as patent licenses. This was true even of research conducted at universities, which under Bayh-Dole looked to spawn start-up firms and generate royalties from patent licenses. A major portion of publicly funded research occurred in large university hospitals in the course of clinical procedures. Such activities could generate significant revenue for the hospitals, while also advancing development of new drugs and treatment regimens provided by profit-seeking firms. Even R&D aimed at enhancing national security, although often shrouded in secrecy, apparently drew with increasing frequency upon technologies developed for private commercial purposes.

In certain respects, these changes in U.S. R&D marked a return to attributes characteristic of the dawn of the twentieth century, when a small cadre of corporations first established distinct programs of research and development housed in separate facilities and staffed by university-trained scientists and engineers. As historian Thomas Hughes once noted, these pioneering institutions were “no philanthropic asylums.” Corporations did not set researchers up with funding and facilities and turn them loose, free to work on problems of their own choosing, in isolation from the financial concerns of the firm. The pioneers sought remedies for pressing technical problems of vital commercial importance. In pursuing them, they were often willing to search outside the boundaries of the firm and acquire rights to technologies developed elsewhere. Much of what would later come to be characterized as R&D occurred in smaller firms, which might use the fruits of their labors to enhance internal operations or bring new products to market, but increasingly licensed them to others. Government contributed with research on areas of vital economic interest such as natural resources, mining, and agriculture, much as it currently underwrites much research devoted to health and defense.

Whether this return to an earlier age best serves the national interest in the Twenty First Century, as nations such as China invest heavily in basic research conducted at universities, remains an open question subject to frequent debate. Absent a compelling threat to public health and welfare or to national security, such as that provided by the Soviet nuclear arsenal at the height of the Cold War, history suggests the U.S. is unlikely to commit significant public funds to such an endeavor.

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