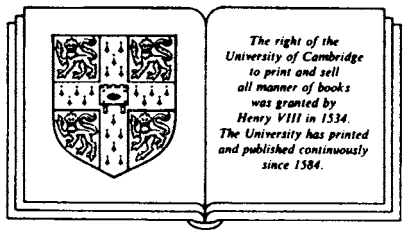
The Making of American Industrial Research

Science and Business at GE and Bell, 1876–1926

LEONARD S. REICH
Rutgers University



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Introduction: The Importance of Industrial Research

Industrial research has changed the way America does business. The first major American industrial research laboratory opened its doors in 1900, inaugurating a new century of profits and progress. But such catchwords do not tell the entire story. Industrial research labs are complex institutions. They have had considerable influence not only on the companies that supported them, but on competition between companies, on the relationship of science and technology, and on the structure of industry. In the study that follows, I examine the forces that brought these labs into being and try to explain why industrial research took root in America in the period from the turn of the 20th century to the First World War. I look in detail at the experiences of two companies and their research programs: General Electric (GE), formed in the merger of Edison General Electric with the Thomson–Houston Company in 1892, and the dominant force in the American electrical industry ever since; and American Telephone and Telegraph (AT&T), the commercial outgrowth of Alexander Graham Bell's 1876 invention of the telephone.

The laboratory that GE established in late 1900 brought to America a type of research institution pioneered by the German chemical and pharmaceutical industries several decades before.[1] Although the GE Research Laboratory was opened with strong corporate interest in the advance of diverse electrical and mechanical technologies – from dynamos to electric locomotives – expectations clearly focused on the technology most closely associated with the company since the time of Edison, the one that had brought much of its sales and profits – the electric lamp. During its first ten years, the Research Laboratory worked hard not only to maintain the company's dominant place in the electric lighting market, but to establish its own indispensibility to GE. Its ultimate success, after a somewhat difficult start, served as both a stimulus

and an example for the American industrial research laboratories established in the years before the Great Depression of the 1930s.

The story at AT&T was in many ways similar. Founded in 1911 because of corporate concern over developing technologies that threatened the company's central market in wired-telephone service, the new research laboratory worked to advance and control those technologies. It later went on to supply the Bell System with opportunities for commercial exploitation while continuing to defend the System's telephone interests. Like GE's laboratory, AT&T's served as both a stimulus and an example for those that followed.

And follow they did. By 1931, more than 1,600 companies reported that they supported research laboratories, employing nearly 33,000 people in all. The Depression brought some cutbacks, but expansion began again during the second half of the 1930s; by 1940, more than 2,000 companies maintained laboratories, with a total of almost 70,000 employees. The largest laboratories grew the fastest. In 1940, for example, 82% of the research personnel in the electrical industry were employed by one-quarter of the companies. Although precise figures are not available, total expenditures for American research laboratories were in the range of $100–$160 million in 1930, and $225–$250 million in 1940. Research activity actually expanded faster than the economy, even when the economy itself was growing rapidly during the 1920s.[2]

Not all corporate laboratories, however, were of the industrial research type, and these figures undoubtedly overstate the number of labs, workers, and resources committed to industrial research activities. Most of them were, in fact, testing or engineering labs, where scientists and engineers labored to assure consistency and efficiency in production. While researchers may have been very effective in this restricted role, close association with manufacturing and testing activities usually limited the scope of their work and the range of contributions they could make. For companies to realize all the advantages of industrial research required that laboratories be set apart from production facilities, with no direct responsibilities to them; that scientists and engineers be hired for the purpose of conducting long-term projects that depended heavily on the development of deeper understandings of related science and technology; and that the laboratories be carefully organized and administered to keep them insulated from most immediate demands, while remaining responsive to business needs in the long term. Until the 20th century, such labs did not exist in America,

and even then the majority of industrial laboratories were not of this type. In fact, the two laboratories considered in this study did not start out that way. They had to prove themselves before securing the level of autonomy needed to become industrial research institutions.

Industrial research can thus be characterized as follows: industrial laboratories set apart from production facilities, staffed by people trained in science and advanced engineering who work toward deeper understandings of corporate-related science and technology, and who are organized and administered to keep them somewhat insulated from immediate demands yet responsive to long-term company needs. Many research laboratories in industry did not fulfill these three basic requirements – for example, most general engineering labs – so, by this definition, they were not practicing industrial research. Although such laboratories did contribute to the development of industrial technology, they were the direct outgrowths of the analysis, testing, and engineering labs that took root in American industry during the years after the Civil War. Their limited roles and approaches to research and development restricted the type of contributions they could make.

It is clear from the figures given above that, by the end of the 1920s, a large number of American companies had become committed to research of some sort. Even though this activity spread throughout the economy, industrial research *per se* concentrated in those areas that were most technologically sophisticated, whose products were most closely associated with the scientific disciplines, and which showed promise of continuing to advance – areas like chemicals, electric power and communications, petroleum refining, photography, and rubber.[3]

The growth of research activity in general – and industrial research in particular – had substantial impact on the American economy. It increased productivity, brought forth new products, and changed the competitive environment. Some of the most important results from industrial research laboratories were the specialized knowledge, technical expertise, and patent rights that enabled companies to improve their products and processes, to protect their markets, and to threaten the interests of competitors.

Not surprisingly, industrial research had a profound effect on the competitive environment and on the structure of American industry. Companies that supported well-funded and well-organized industrial research laboratories developed significant advantages over their competitors. They became the centers of power

in their industries, and only those other companies with similar operations could compete with them on equal terms. This relegated to a lesser position those unwilling or unable to maintain such laboratories and made it exceedingly difficult for independent inventors to gain a foothold in the market areas of interest to companies supporting industrial research.[4]

With the advent of industrial research, large companies could begin to control the rate and direction of technological change. Because science and technology had internal dynamics of their own, and no person or corporation could foresee or direct exactly how they would develop, complete control remained elusive. Yet through their laboratories' extensive research and development activities, orchestrated to produce not only new products and processes but also patents and technical expertise relating to important market areas, companies could circumscribe technological development so that it did not undermine their commercial positions or threaten their investments. A company maintained a strong position by staying in the forefront of research activity in areas germane to its primary markets, developing new products there, and gathering patents to prevent others – even those with new and revolutionary products – from being able to do the same. This could be accomplished through ownership of numerous "secondary" patents, which were almost always needed for commercial production. Sometimes a company's possession of strong patent rights for technologies in which it had no direct interest could be used to threaten the positions of competitors, yielding important ammunition in wars for market control.

Industrial research provided many of the resources needed for the corporate management of change. Through their laboratories' efforts, research-oriented companies made manufacturing operations more efficient, developed new production methods, and exerted considerable influence on the evolution of the marketplace through the advance and control of technology. Industrial research contributed to the effort in a number of ways. Procedures established in the laboratories assured that significant new ideas and results in science and technology came to the companies' attention, so that they were not caught unawares by new developments. The laboratories supplied patents to prevent competitors from encroaching on the companies' commercial turf, and they used the expertise acquired in research to design new manufacturing operations, to improve existing ones, and to locate the sources of

trouble when difficulties with materials or methods threatened fabrication processes.

Industrial research also brought to the companies that pursued it a benefit somewhat less tangible but no less important: the progressive image associated with the advance of science and technology. This proved very useful for advertising, through which consumers were directed to associate "progressive" firms with the most desirable products. The support of industrial research and the image that it brought also helped protect companies from antitrust prosecution because public benefits from research could be seen as outweighing the detriments of restraint of trade under the U.S. Supreme Court's "Rule of Reason."[5]

Naturally, what benefited some companies in a competitive environment posed difficulties for others. Companies that lacked the substantial resources to support industrial research, those that had large investments in established products and production methods and were unwilling to abandon them, or those without the stable internal structures that led corporate managers to look beyond their immediate organizational problems to the larger questions of market development and defense, ultimately found themselves in disadvantageous positions relative to their better-organized and more aggressive competitors who undertook industrial research.[6] And of course, independent inventors, faced with these so-called invention factories found important areas of development preempted and opportunities to exploit their own inventions closed off. Whereas their only competition in new fields had previously been rival inventors, now they faced the organized onslaught of industrial research.

As industrial research took form at a number of companies in the early years of the 20th century, it helped to change the perspectives of corporate managers. Companies usually established research programs to protect their interests in particular market areas, but soon found that their laboratories had far greater capabilities. Scientists and engineers, organized into teams and set to work in fields germane to company interests, frequently made significant advances in both science and technology, presenting their employers with entirely new products and processes to exploit. Researchers developed small-scale manufacturing operations for new products and then transferred them to the factory, providing considerable impetus to the companies' total innovative processes.[7] As industrial researchers took their work into fields

beyond those directly associated with company needs, they tried to acquire patents that might in the future prove vital to their own company's ability to enter new markets or – sometimes just as importantly – that could help prevent others from doing so. Such patents might be used in a number of ways, from stymieing competitors to trading with them for other patent rights or commercial concessions. In short, these patents, along with the new products, processes, and technical expertise developed in industrial research, presented corporations with new opportunities for innovation, market control, and growth. Before long, corporate management took advantage of these opportunities by expanding into new product areas, rationalizing and developing new production processes, and attacking competitors who threatened to invade their markets.

Science, technology, and industrial research

The impact of industrial research in America reached beyond the realm of business, strongly affecting science and technology as well. Industrial research provided American science and technology both support and direction. It also offered career opportunities for scientists and engineers at a time when their other options remained quite limited. When the first laboratories were established early in the 20th century, most American scientists had little time or support for research. Many taught at colleges and universities oriented toward classical learning, where they received neither incentives nor facilities to pursue research. Others worked in state universities or engineering colleges whose teaching loads were so heavy and whose equipment was so poor that conducting original work proved to be almost impossible. A few graduate-level, research-oriented science and engineering departments did exist by the turn of the century, but the number of people who could be accommodated in them remained quite small.

Industrial research laboratories offered American scientists and research-oriented engineers a welcome new career path. While a few scientists had been employed by American industry even before the Civil War, in most cases their purview had been limited to the testing and analysis of materials. Industrial research presented a considerably better opportunity: Scientists and engineers could devote a major portion of their time to activities oriented toward gaining deeper understandings of science and technology;

they commanded substantial resources; and they were provided with trained assistants to carry out the more technical or more mundane tasks of research and development. Industrial researchers often had restrictions placed on them in matters of publication and participation in professional organizations, but those more interested in the methods of science than concerned with either the advance of scientific disciplines or the trappings of the profession could find a comfortable home in industrial research. Though they had to set aside some of the pressing questions of the scientific disciplines to concentrate on those areas of research of importance to industry, this was a deal that many willingly made.[8]

Working in industrial research thus presented personal and professional trade-offs. Once in the labs, scientists and research-oriented engineers escaped the pressures of the academic environment, including teaching and directing students. They could invent without having to act as entrepreneurs, yet be paid quite well – far better than in comparable academic positions – and higher pay held particular allure in a country where personal worth was often measured by the size of one's paycheck. As industrial researchers, they accepted the responsibilities of record keeping, providing consulting services, and working for patents. In return, they received large amounts of research time, considerable support and assistance, and substantial financial reward. For many, it was a satisfactory, even satisfying, alternative.

As the industrial research laboratories at a number of corporations took form, they became quite different from earlier American labs. The demands placed on industrial researchers and the way in which they approached their work were peculiar to the new environment. Industrial research scientists and engineers often worked on group projects, to which they contributed specified types of results under the direction of a group leader. Their leeway for digression was often quite small, and they sometimes faced schedules for the completion of their work. Because research directors had to be certain that a large portion of results coming from their laboratories would be commercially applicable, they frequently supervised projects themselves or placed them under the control of a senior staff member. Individuals did not have to be brilliant to make important contributions to a project's success. Administrators took advantage of the complementary capabilities of their researchers, sometimes setting theorists and experimentalists, abstract thinkers and "nuts and bolts" people working together. The power of such a team to find solutions usually surpassed

the sum of the powers of the individuals taken separately. In instances when such team projects were not used, administrators relied heavily on the strong influence of the commercial environment, which made researchers aware that they were expected, one way or another, to make their work pay.[9]

In industrial research, science and technology were pursued together in order to improve technologies of corporate interest. Science and technology were perceived, not as they had been through much of history – as two endeavors separated by purpose, methodology, and even the social classes of the practitioners – but rather as complex, interrelated activities aimed at a common goal. In fact, science and technology became so fully intertwined in many industrial research projects that it is impossible for the historian to distinguish between them. In this new approach to research, science and technology were each informed by and closely related to the other; they benefited greatly, both individually and collectively.

Yet, with only a few exceptions, the results of industrial research have been advances of science and technology in preconceived directions, because researchers and research directors usually had to foresee the types of results coming from projects in order to justify their support. By the very nature of preconception, the results were rarely revolutionary. Commercial and financial exigencies made most companies unwilling or unable to give many of their scientists and engineers the research freedom needed to pursue revolutionary change. Rules, regulations, and red tape limited the researchers' initiative and the scope of their work, while the need to produce a regular stream of results for corporate consumption forced many research directors to favor short-term, low-risk projects over longer-term undertakings which were less certain of applicable results. Thus the control and bureaucratization of research had a profound impact. At the same time, the market power of companies supporting industrial research was often so strong that it inhibited research and development in smaller companies, in university laboratories, and by individuals. Under certain circumstances, then, industrial research had an adverse impact on the pursuit of science and technology.

But even when these limitations and inhibitions are taken into account, one can hardly help but conclude that industrial research has, on balance, strongly promoted the pursuit of science and the advance of technology. The tremendous power of the combined science–technology approach, along with the substantial corporate

resources committed to research, assured that a considerable amount of new knowledge about and control over the natural and man-made world would come from industrial research. That, given their levels of funding, industrial laboratories contributed relatively little to solving the outstanding problems of the scientific disciplines was of no particular concern to the companies supporting them, nor should it detract from the value we ultimately place on their results.

Industrial research combined science and engineering to create much of what we today call "high technology." Yet, not everyone considers all of it – from electronics and computers to synthetic materials and "wonder drugs" – as advances. Some of these developments tended to cause social dislocations, exacting a price from their users in one way or another, or they created as many social and economic problems as they solved. Other developments worked to concentrate power in the hands of those who already had more than their share of it, including the companies that supported industrial research.[10] Thus we can say that industrial research has been extremely successful in the advance of technology only so long as we understand that advance to be in the directions desired by major corporations.

The advent of industrial research had considerable impact on the communities and professions of science and engineering, on American industry, and through industry, on the lives and careers of most of the nation's people. The study that follows is an attempt to come to grips with the reasons for and importance of this phenomenon. It will look at how and why conditions in the late 19th and early 20th centuries led to the establishment of industrial research and will then go on to consider in detail the laboratories at GE and Bell. It will also examine the research projects they undertook in their early years and will consider their organization and methods of research, the relationship of the laboratories to the companies of which they were parts, and the commercial value of their results.

The main purpose in studying these relationships is to understand how industrial research influenced developments in science, technology, and industry. I try to show the ways in which it affected the rate and direction of changes in technology as well as how companies introduced new technology into the economy. Given the various advantages discussed above, I consider how industrial research changed the ways companies approached market control, innovation, and growth, and how the industrial en-

vironment influenced researchers' conceptions of their projects, the methods that they used, and the kinds of results that they achieved. I also attempt to determine why the first American industrial research laboratories were established in the years between the turn of the 20th century and the First World War. There are a number of reasons, including changes in the content and methods of science and technology during the 19th century; increases in the quantity and enhanced capabilities of available researchers; commercial threats to American industry based on developments in science and technology, especially abroad; changes in the structure of American industry in the late 19th and early 20th centuries; and social and political forces, including antitrust legislation that forced companies to adopt new ways to innovate and compete.

Taking these factors into account and answering all of the questions set out above requires consideration of the type of business and the market position of each company establishing industrial research. Of course, every company was unique, so the answers will be somewhat different for each. Because the study that follows deals with a very limited sample, the conclusions for industrial research as a whole must necessarily be tentative. Nevertheless, I chose GE and Bell as the two major case studies because they had overlapping areas of interest in science and technology, but very different corporate structures, operating methods, and market positions. Hence an examination of these questions in relation to the two companies should provide results more closely related to differences in corporate structure, outlook, and opportunity than to the science and technology involved.

GE and Bell provide examples of research activity at two large technology-based corporations that took form in the late 19th century and have played influential roles in the American economy ever since. These companies gained and maintained their positions in large part through their research work, so this study will look at the many ways it proved useful to them. Although the two cases do not comprise the entire story of American industrial research, they provide good starting points because both laboratories were influential in the industrial research movement that followed the First World War, and because many companies learned from the examples that they set.

Before taking up the story of industrial research at GE and Bell, however, it is important to survey the American environment that made such endeavors both possible and, from the companies' points

of view, necessary. In the chapter that follows I discuss the developments in science, technology, and industry during the 19th century that led these and other American companies to undertake industrial research.