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# Independent Inventors in an Era of Burgeoning Research & Development

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The early twentieth century represented a transitional period in the history of American innovation. Historians have typically assumed that the rise of industrial research labs at firms like General Electric and AT&T signaled an end to the era of heroic, independent inventors such as Thomas Edison and Alexander Graham Bell. However, a close look at the historical U.S. patent data shows that patents granted to individual inventors outnumbered corporate patents until the early 1930s and represented nearly 50 percent of total patents through the 1950s. In this paper, I explore the case of independent inventor Samuel Ruben and his primary licensee, the P. R. Mallory Company. Unlike earlier inventor-entrepreneurs, Ruben preferred to license his patents to manufacturing firms and to serve as their consultant. Meanwhile, Mallory followed a hybrid innovation strategy, working with outside inventors like Ruben while simultaneously investing in its own integrated research and development laboratories. For Mallory, the locus of innovation resided both inside and outside the firm.

The early twentieth century represented a transitional period in the history of American innovation. Historians have typically agreed that the rise of corporate industrial research at firms like General Electric and AT&T (American Telephone and Telegraph) signaled an end to the nineteenth-century era of heroic, independent inventors such as Thomas Edison and Alexander Graham Bell. Thomas P. Hughes has succinctly captured this interpretation, suggesting that, after World War I:

> . . . the independents never again regained their status as the pre-eminent source of invention and development. . . . Industrial scientists, well publicized by the corporations that hired them,

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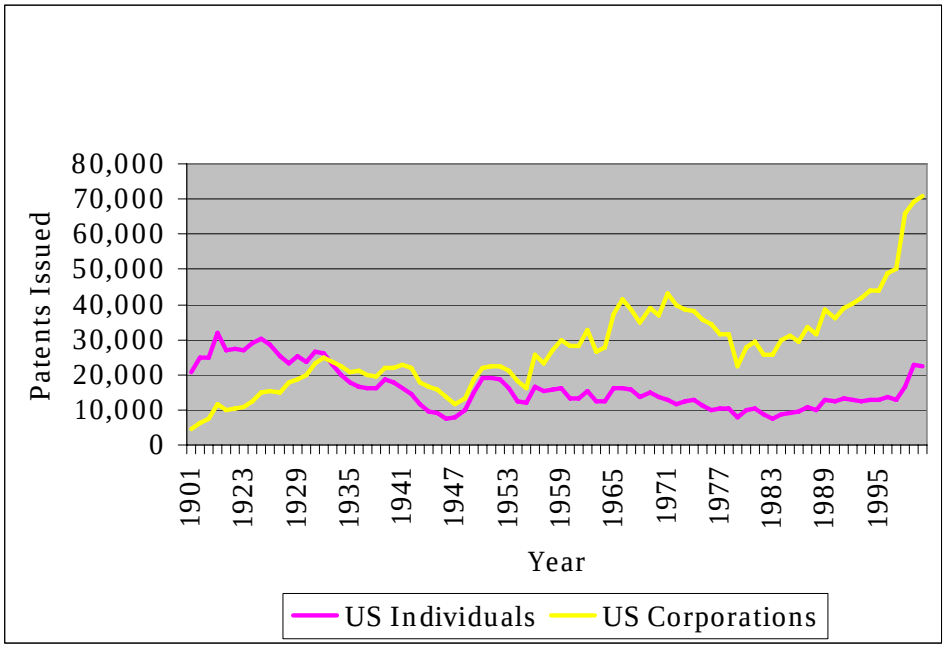
> steadily displaced, in practice and in the public mind, the figure of the heroic inventor as the source of change in the material world.[1]

However, a close look at the historical patent data tells a different story (see Figure 1). Patents granted to individual inventors outnumbered corporate patents until about 1933, and they still represented nearly 50 percent of total patents throughout the 1950s. In fact, the dominance of corporate over independent patenting does not occur until after 1955.[2] Yet, the world was obviously changing for the independents, so I am curious about their collective experience. Were there really so few independent inventors in the twentieth century, or have their stories simply not been told? Generally, what was it like to operate as an independent inventor after 1900, an era of burgeoning R&D (research and development)?

FIGURE 1
U.S. Patents Issued to Individuals vs. Corporations, 1901-2000




Source: Table Cg27-37, "Patent Applications Filed and Patents Issued, by Type of Patent and Patentee: 1790–2000," in *Historical Statistics of the United States: Earliest Times to the Present*, ed. Susan Carter et al., 5 vols. (New York, 2006), 3: 425-29.

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[1] Thomas P. Hughes, *American Genesis: A Century of Invention and Technological Enthusiasm, 1870-1970* (1989; New York, 2004), 138-39.

[2] See Table Cg27-37, "Patent Applications Filed and Patents Issued, by Type of Patent and Patentee: 1790–2000," in *Historical Statistics of the United States: Earliest Times to the Present*, ed. Susan Carter et al., 5 vols. (New York, 2006), 3: 425-29.

To explore these questions, I will begin with the case of independent inventor Samuel Ruben, describing his business model and successful career working with an assortment of firms. Next, I will describe the hybrid innovation strategy of Ruben's primary licensee, the P. R. Mallory Company, as well as Mallory's long-term, mutually beneficial relationship with Ruben, a collaboration that lasted several decades. Finally, I will suggest how our current models of innovation are inadequate to describe their partnership, and suggest a new model.

## Independent Inventor Samuel Ruben

Samuel Ruben (1900-1988), born in Harrison, New Jersey, in 1900, grew up in New York City. In his youth, Ruben exhibited many characteristics commonly associated with earlier nineteenth-century independent inventors. He performed his own self-directed electrical and chemical experiments starting at the age of eleven, and as an amateur ("ham") radio operator, he built and tinkered with radio sets using available spare parts. Although Ruben possessed only a spotty education and never earned a Bachelor's degree, he Ruben was able to obtain financial backing in his early twenties to establish Ruben Laboratories in New York City in 1922.[3] Ruben later moved his lab north to New Rochelle in 1930, where he worked until retiring in 1984.[4]

Ruben Laboratories was a small shop and initially Ruben himself was the only employee.[5] He purposely kept the staff small, normally employing no more than one or two assistants.[6] His investors carried the lab financially for

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[3] Later in his career, Ruben received honorary doctorates from Brooklyn Polytechnic Institute and Columbia University. In addition, in 1959, "trustees of Butler University, Indianapolis, conferred on him a doctorate of science, 'on the recommendation of the faculty,' who were so impressed by his scientific achievements that they did not recommend that it be an honorary degree. Thus Samuel Ruben became Dr. Ruben, although he never formally enrolled in any university." See "The Wizard of New Rochelle," *Business Week* (4 Nov. 1967), 69.

[4] The best source on Ruben's life and career is his autobiography; see Samuel Ruben, *Necessity's Children: Memoirs of an Independent Inventor* (Portland, Ore., 1990), quotation at p. 27. Another helpful sketch is Alfred Steinberg, "Sam Ruben: Born to Invent," *Reader's Digest* 90 (May 1967): 155-60. Also helpful is Henry B. Linford's sketch of Ruben prior to Ruben's receiving the American Electrochemical Society's Acheson Medal, 6 Oct. 1970 in Atlantic City, printed as Henry B. Linford, "Samuel Ruben—Acheson Medalist," *Journal of the Electrochemical Society* 118 (Jan. 1971): 11C-13C.

[5] "In order to really appreciate the accomplishments of the Ruben Laboratories, one must realize that this was initially a one-man operation; for the first three years he did everything in the laboratory himself—swept the floors, cleaned the beakers, blew the glass, did everything. As the business progressed he hired a helper or two." See Linford, "Samuel Ruben – Acheson Medalist," 12C.

[6] "Ruben works with two long-time aides, Fred D. Williams, Jr., an electrical engineer, and William Sauerbrey, a technician. There are no other staff m.s. 'We

its first three years, until Ruben licensed a new solid-state rectifier to the P. R. Mallory Company in 1925.[7] The arrangement was typical of Ruben's career. Unlike nineteenth-century "inventor-entrepreneurs," Ruben had no interest in exploiting his own inventions, preferring instead to collect royalties and to leave the manufacturing and marketing to his licensees.[8]

As knowledge of Ruben's expertise grew in industry circles, he was able to supplement his royalty income by serving as a retained consultant to a host of companies. Ruben typically consulted for the companies he licensed, staying connected in order to fix problems that came up during the development stage, or to adapt his inventions to new applications. For example, in 1928, Ruben licensed his quick-heating amplifier tube to the Arcturus Radio Tube Company and subsequently visited their Harrison, New Jersey, lab "once a week as a consultant at a high fee" for the next two years.[9] Ruben often consulted for direct competitors in the same industry including battery makers Mallory and Ray-O-Vac.[10] As a consultant, Ruben had no particular loyalties; in this sense, he was truly independent.

Of all of Ruben's licensees and consulting arrangements, his relationship with the P. R. Mallory Company was the longest and most productive. Philip Rogers Mallory founded the company in 1916 as a supplier of tungsten wire filaments to light bulb manufacturers. Over time, Mallory expanded its product line and offered a range of components: the resistors, capacitors, and timers that went into other companies' products.

During World War II, Mallory licensed Ruben's most famous invention, the miniature mercury battery, and supplied great quantities to the Army Signal Corps for use in portable walkie-talkies and mine detectors. Over the next several decades Ruben and Mallory worked together to commercialize the miniature mercury battery for use in hearing aids, pacemakers, and

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purposefully keep it small,' says Ruben. 'It's less complicated that way.' " See "The Wizard of New Rochelle," 70.

[7] Samuel Ruben, U.S. Patent 1,751,359, "Asymmetric Electric Couple." Filed 20 Aug. 1925, issued 18 March 1930. Ruben licensed the patent-pending rectifier to the Elkon Works, a Mallory subsidiary, in June 1925. See Samuel Ruben, "History and Development of Dry Electrolytic Capacitors," *Electrochemical Technology* 3 (Nov.-Dec. 1965): 301-7, quotation at p. 301.

[8] As Thomas P. Hughes has written, "inventor-entrepreneurs were not content to invent and leave the development and introduction of the invention into the market to others." See Thomas P. Hughes, "Edison's Method," in *Technology at the Turning Point*, ed. William B. Pickett (San Francisco, 1977), 5-22, quotation at p. 7. "He [Ruben] confined himself to inventing, left production to private firms—principally the P. R. Mallory Co.—which he licensed." See Steinberg, "Sam Ruben: Born to Invent," 159.

[9] Ruben, *Necessity's Children*, 63.

[10] Ruben's correspondence files (1937-1984) are filled with letters from dozens of companies, including those specifically mentioned. See box 9, file folders 1 through 3, Papers of Samuel Ruben, Othmer Library of Chemical History, Chemical Heritage Foundation, Philadelphia, Pa.

electric watches. Ruben also worked with Mallory to develop today's standard alkaline batteries. In the process, the company evolved into the multi-billion dollar company we know today as Duracell.[11]

## Mallory's Mixed Innovation Strategy

One of the most remarkable aspects of Mallory's commercial success was its hybrid, multi-faceted approach to innovation. Besides Samuel Ruben, Mallory worked with a dozen or more independent inventors and outside consultants, while simultaneously investing millions in its own vertically integrated industrial research laboratories. For Mallory, the institutional locus of invention resided both inside and outside the firm.

In his memoirs, company founder Philip Rogers Mallory admitted, "one of my idiosyncrasies has been a liking for collaboration with the individual creative minds which come under the head of 'inventors.' "[12] Besides his "prize example" Samuel Ruben, Mallory noted with satisfaction the company's dealings with independent inventors Paul Ware and Fred Hooven. In the 1930s, Ware approached Mallory with a variable inductance tuner for television sets, which the company manufactured and sold to DuMont, Crosley, and other television manufacturers.[13] Likewise, Mallory worked closely with Hooven, who developed an interval bomb timer that became standard equipment on most American bombers in World War II.[14] Besides Ruben, Ware, and Hooven, Mallory worked with a dozen other independent inventors whose inventions were not promising enough to add to the company's product line.[15] Nevertheless, independent inventors had a

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[11] There are two good histories of P. R. Mallory & Co., Inc. The first is a combination memoir and corporate history by the company's founder and namesake; see Philip R. Mallory, *Recollections: Fifty Years with the Company* (Indianapolis, 1966). The second history is a short pamphlet written by a former employee; see Edmund E. Taylor, *Bits of Mallory History: 70 Years, 1916-1986* (Indianapolis, 1986). On the evolution of Mallory to Duracell, see Eric S. Hintz, "Portable Power: Inventor Samuel Ruben and the Birth of Duracell," unpublished manuscript, April 2007.

[12] Mallory, *Recollections*, 165.

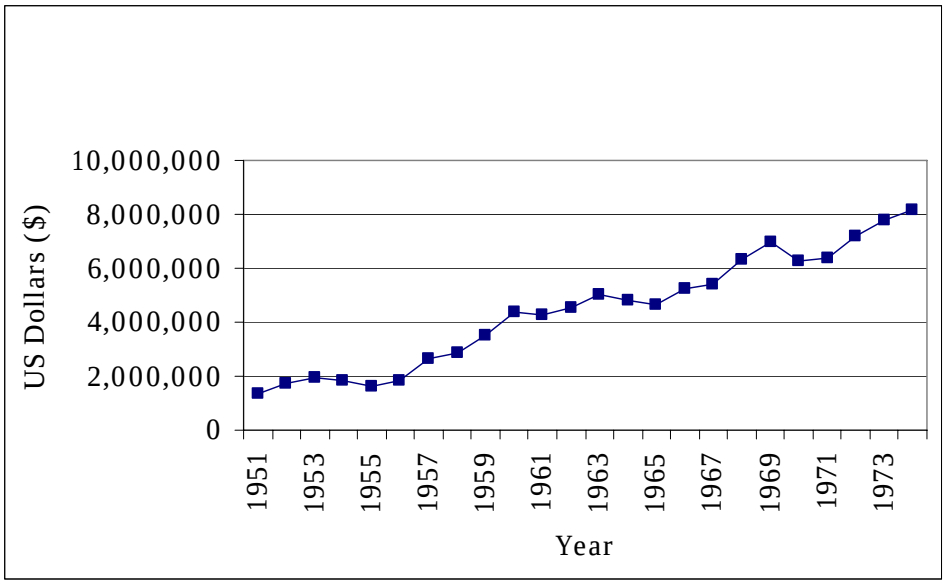
[13] On Paul Ware, see Taylor, *Bits of Mallory History*, 8. Also, see Mallory, *Recollections*, 166.

[14] Working with Hooven, Mallory also developed a bomb release mechanism and a bomb rack selector that were also widely used across the air branches of the armed forces. On Hooven, see Mallory, *Recollections*, 99, 165-66. For a good overview of Hooven's peripatetic career, see Myron Tribus, "Frederick Johnson Hooven," in *Memorial Tributes*, ed. National Academy of Engineering, 11 vols. (Washington, D.C., 1979-2007), 3: 200-205.

[15] Mallory listed the dozen or so "non-productive" collaborations with the following inventors: John Lewis Andrews, Madison Cawein, Duncan Cox, Giles S. Moore, W. J. Polydoroff, Caton Bradley, Kurt Schimkus, Charles W. Sidney, Walter J. Six, Harry Waters, James L. Yarian, Harold Brown, and Reginald Dean. See Mallory, *Recollections*, 166-67.

receptive audience at Mallory and remained an important part of the firm's innovation strategy.

FIGURE 2
P. R. Mallory Research, Development, and Engineering Expenditures, 1951-1974




Source: P. R. Mallory & Co., Inc., "Annual Reports," 1951-1974.

After World War II, Mallory continued to work with independent inventors, while simultaneously investing in its own vertically integrated industrial research laboratories. Following Bell Labs' announcement of the transistor in 1947, component makers like Mallory became acutely aware of the revolutionary nature of solid-state electronics. To meet the challenge, Mallory formed a Central Research Division in 1953 in Indianapolis. Unlike the divisional engineering staffs, which improved and extended existing product lines, the charge to the Central Research Division was "investigating new ideas that might result in new components."[16]

In the years that followed, Mallory consistently increased its R&D investments, which ranged from 3 to 4 percent of annual sales (see Figure 2).[17] In 1962, the company made another substantial R&D investment by opening the Laboratory for Physical Science in Burlington, Massachusetts. Mallory's directors described the new "basic research center" in their 1962 Annual Report:

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[16] Ibid., 160. This separation of divisional/central research responsibilities is foreshadowed in P. R. Mallory & Co., Inc., "Annual Report Year Ended Dec. 31st, 1951," 26-27.

[17] P. R. Mallory & Co., Inc., "Annual Reports" from 1951 through 1974.

> It is devoted primarily to fundamental research in such areas as electrochemistry, materials, thin-film technology, and solid-state physics. . . . In our expanded program of basic and applied research, we are bringing together scientists of many disciplines. . . . We are confident that that this approach will open new doors to technological achievement.[18]

In this vertically integrated laboratory, scientists with doctorates conducted their investigations as salaried Mallory employees and assigned their patents to the company. In fact, founder Philip Mallory proudly reported that the company's employees "filed 77 patent applications in 1965. During the year, 23 patents were issued to employees assigned to the company, more than doubling the number issued in 1964."[19]

While justifiably proud of the company's industrial research capabilities, Philip Mallory reminded readers of his memoir that they should not forget how his company had "collaborated with the creative inventors outside our own ranks."[20] Mallory was truly ecumenical in its approach to innovation and rejected what Ruben called the "Not Invented Here" factor—that is, "the inherent reluctance of the technical staff of [a] prospective licensee to accept outside ideas."[21] Rather, Ruben appreciated the company's openness to new ideas, and reported that founder Philip Mallory was "never afraid to take on new products or to consider new ideas whether they emanated from within or from outside the Mallory Company."[22]

## Models of Innovation

Mallory's mixed innovation strategy does not fit neatly into the analytical frameworks previously assembled by scholars who have considered the institutional locus of innovation. Thomas Hughes has described late nineteenth- and early twentieth-century "inventor-entrepreneurs" such as Thomas Edison and Elmer Sperry, who formed eponymous companies to manufacture and exploit their own inventions.[23] Naomi Lamoreaux and Kenneth Sokoloff have introduced a related framework whereby less entrepreneurial (or perhaps less successful) inventors specialized only in the inventive act, selling or licensing their patents in the open market to

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[18] P. R. Mallory & Co., Inc., "1962 Annual Report," no page numbers.
[19] Mallory, *Recollections*, 164.
[20] Ibid., 161. This statement is noteworthy as it comes in chap. 13 of his memoir entitled "Some Aspects of Research," which focused on Mallory's integrated industrial research capabilities.
[21] Samuel Ruben, "Imaginative Thinking, and Opportunities Afforded an Independent Inventor by the American Patent System," *Journal of the Patent Office Society* 49 (June 1967): 442-56, quotation at p. 456.
[22] Ruben, *Necessity's Children*, 110.
[23] On inventor-entrepreneurs, see Hughes, "Edison's Method," 7.

companies that manufactured and sold their inventions.[24] Finally, Chandlerian business historians have described how the largest turn-of-the-century firms internalized inventive activity, forming vertically integrated industrial laboratories that created innovations within the firm.[25]

However, none of these frameworks adequately describes the complex contours of Mallory's mixed innovation strategy and the place of independent inventors within it. Though Philip R. Mallory founded his own eponymous company, he was simply an entrepreneur, not an inventor. Ruben was an inventor, but not an entrepreneur, preferring to let his licensees manufacture his inventions. Moreover, Chandlerian frameworks have typically assumed that integrated industrial labs supplanted independent inventors as a source of innovation, yet this was clearly not the case at P. R. Mallory, which continued to work profitably with independents even while investing in its own R&D capabilities.

The second framework—firms pursuing outside inventions—most closely approaches the situation at Mallory, but is insufficient. Licensing patents in the open invention market was certainly a rational strategy for a medium-sized firm like Mallory, concerned with the costs of invention.[26] By outsourcing some of its inventions, Mallory reduced some of the fixed capital costs of staffing and outfitting a lab, while allowing outside inventors to

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[24] On specialized inventors and the open market for inventions, see Naomi R. Lamoreaux and Kenneth Sokoloff, "Inventors, Firms, and the Market for Technology in the Late Nineteenth and Early Twentieth Century," in *Learning by Doing in Markets, Firms, and Countries*, ed. Naomi R. Lamoreaux, Daniel M. G. Raff, and Peter Temin (Chicago, 1999), 19-60.

[25] In *The Visible Hand: The Managerial Revolution in American Business* (Cambridge, Mass., 1977), Alfred D. Chandler, Jr. described how the largest industrial firms vertically integrated and coordinated their operations using the "visible hand" of corporate managers to mitigate the exigencies of capricious markets. According to John K. Smith, "The organizational approach to understanding big business developed by Alfred D. Chandler, Jr., has given historians a framework within which to place the research laboratory." See John K. Smith, "The Scientific Tradition in American Industrial Research," *Technology and Culture* 31 (Jan. 1990): 121-31, quotation at p. 121.

[26] I consider P. R. Mallory to be a medium-sized firm, because it consistently fell short of the threshold set by Alfred Chandler, whose studies examined the two hundred largest industrial firms. See Alfred D. Chandler, Jr., and Takashi Hikino, *Scale and Scope: The Dynamics of Industrial Capitalism* (Cambridge, Mass., 1994). For example, in 1978, the year of its acquisition, *Fortune* magazine ranked P. R. Mallory the 490th largest American company, with revenues of $367 million. See "Fortune 500: P. R. Mallory"; viewed 10 April 2007. URL: http://money.cnn.com/magazines/fortune/fortune500_archive/snapshots/1978/3295.html.

assume most of the up-front risk and expense of new product development.[27] In its integrated labs, Mallory's research expenditures were a sunk cost, even if the new product flopped. In licensing agreements, however, Mallory's royalty payments were typically computed as a percentage of future sales. Thus, the company paid only if the invention succeeded, and even then, the amortized payments lasted only until the patent expired.[28]

However, there is a risk in narrowly construing the licensing of a patent as a simple market transaction. Though licensed patents often cost less than inventions developed internally, these outside inventions were often saddled with "information asymmetries"; in other words, a firm licensing a patent may not have known the seller very well or exactly what they were buying. Yet, this was clearly not the case with Ruben and Mallory, who worked together for several decades. Rather, we might best construe Ruben and Mallory's arrangement as a long-term relationship. Economic historians Naomi Lamoreaux, Daniel Raff, and Peter Temin have suggested that scholars should move beyond the simple dichotomy of Smithian markets and Chandlerian hierarchies to understand "the broad range of techniques that businesspeople have developed over time to coordinate their activities": "In the middle of these two extremes are long-term relationships—that is, transactions among otherwise independent economic actors in which the parties voluntarily choose to continue dealing with each other for significant periods of time."[29]

Thus, by working with familiar outside inventors, firms such as Mallory avoided some of the expensive overhead associated with vertically integrated laboratories, while mitigating the risks associated with purchasing inventions in the open market.[30] In Mallory's case, the company pursued both strategies

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[27] Economist Kenneth J. Arrow has argued that innovations are commodities that are difficult and expensive to produce, but easily transferable or sold once created. Accordingly, patents purchased from outside inventors should be less expensive than patents developed internally. See Kenneth J. Arrow, "Economic Welfare and the Allocation of Resources for Invention," in *The Rate and Direction of Inventive Activity: Economic and Social Factors*, ed. National Bureau of Economic Research (Princeton, N.J., 1962), 609-26.

[28] For a good overview of the relative advantages of vertical integration vs. outsourcing for innovation, see W. Bernard Carlson, "At Arm's Length or Close to the Vest?: A Historical Look at How Companies Locate Technological Innovation," paper presented to the International Economic History Association Congress, Helsinki, Finland, Aug. 2006.

[29] Naomi R. Lamoreaux, Daniel M. G. Raff, and Peter Temin, "Beyond Markets and Hierarchies: Toward a New Synthesis of American Business History," *American Historical Review* 108 (April 2003): 404-33, quotations on p. 405 and p.407.

[30] This strategy is reminiscent of Philadelphia's nineteenth-century network of small textile producers, who distributed the capital costs and risks of production by cooperating with other members of the network; see Philip Scranton, *Proprietary Capitalism: The Textile Manufacture at Philadelphia, 1800-1885* (New York, 1983).

concurrently, maintaining relationships with independents like Ruben, while simultaneously investing in its own vertically integrated research labs.

## A Long-Term Relationship: Ruben and Mallory

The case of Mallory's long-term relationship with inventor Samuel Ruben provides a rich example of this type of arrangement. Ruben and Mallory initially became acquainted in 1925, when Ruben sent one of his assistants to Mallory's New Jersey plant to purchase some tungsten wire for an experiment. From this serendipitous exchange Mallory learned of Ruben's solid-state rectifier, obtained an exclusive license, and incorporated it into a new battery charger. Ruben continued to work with Mallory and Duracell for the next several decades, through 1982, as shown by a memo from their last cell development project. In all, Ruben and Mallory's long-term relationship spanned fifty-seven years.[31]

Mallory and Ruben Laboratories strengthened their relationship by occasionally trading personnel. For example, Ruben's assistant, Bob Ingham, worked on capacitors at Ruben Laboratories before joining Mallory's capacitor division. Ruben also gained assistants from Mallory, including Fred Williams, the son of Mallory's Indianapolis plant manager, and John Robinson, whom Ruben hired when Mallory closed its New Jersey plant.[32]

However, the most important connection between Mallory and Ruben Laboratories was Leon Robbin. Robbin was Ruben's cousin, and after he finished Georgetown Law School in 1922, Ruben employed him part-time as his patent attorney and sales agent. In 1930, Philip Mallory arranged for Robbin to spend his spare time working in Mallory's New York business office; he became a full-time Mallory employee in 1933 and eventually held several high-ranking posts.[33] Robbin brokered the 1943 deal between Mallory and the Army Signal Corps that resulted in the wartime production of Ruben's mercury batteries, and he led Mallory's postwar commercialization efforts as vice-president of the Battery Division. Though Mallory had never made batteries prior to the war, Robbin's close relationship with his cousin

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[31] The beginning of Ruben and Mallory's relationship is recounted in Mallory, *Recollections*, 138; also see Ruben, *Necessity's Children*, 37-39. Ruben continued to work with Mallory/Duracell through 1982. See D. R. Riter to R. DiPalma, 25 Oct. 1982, box 9, file folder 3, Papers of Samuel Ruben.

[32] Ruben, *Necessity's Children*, 71-73.

[33] See chap. 10, "Lee Robbin," in Mallory, *Recollections*.

Ruben facilitated the company's continuing innovation and transformation into Duracell, today's market leader. [34]

Perhaps the most tangible sign of Mallory's long-term commitment to Ruben was the decision to relocate its battery operations from Indianapolis to Tarrytown, New York, only 20 miles from Ruben Laboratories in New Rochelle. In his memoirs, Philip Mallory confirmed that this May 1946 move was undertaken explicitly to be "close to the inventor's laboratory."[35] In 1963, Mallory unveiled a new and improved Tarrytown Battery Research Center and dedicated the lab to Ruben in a public ceremony. Emanuel Piore, vice-president of research and engineering at IBM (International Business Machines), honored Ruben in a speech entitled "The Independent Inventor in the Contemporary World." Piore noted that Ruben's inventions were

> . . . by one man who was without the resources represented by our large industrial and university laboratories. . . . So we honor a man who in a certain sense has proved that, contrary to popular opinion,

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[34] Mallory had, since 1938, produced and sold another of Ruben's inventions—a "grid bias" cell that supplied a constant voltage on the control grid of three-wire amplifier tubes. In fact, this cell, which was hermetically sealed, had inspired Ruben's invention of the sealed mercury cell. See Ruben, *Necessity's Children*, 85. Leon Robbin later stated, "Previously, the Mallory Company had never made a single battery of any type unless we were to consider the Ruben Vanadium pentoxide-glycoborate-cadmium grid bias cell a battery." See Mallory, *Recollections*, 206.

In his memoirs Philip Mallory, acknowledged Robbin's role as the "glue" cementing the company's relationship with Ruben: "It is impossible to give sufficient credit to his [Robbin's] efforts in organizing the force that was presenting an entirely new type of dry battery to commercial markets. His cooperation with Sam Ruben was responsible for a remarkable speed-up of adaptations of war-time uses. . . . Lee is a good example of how great the understanding of human relations can stimulate an organization. He was a fine go-between in my relations with Sam Ruben." See Mallory, *Recollections*, 104.

In 1964, Mallory re-branded, adopting the name Duracell® for its batteries; see P. R. Mallory & Co., Inc, "1964 Annual Report," n.p. In 1978, the conglomerate Dart Industries acquired Mallory. Although Dart spun off most of Mallory's component divisions, it kept the battery division as a subsidiary, renaming it "Duracell International, Inc." See Robert J. Cole, "$233 Million Dart Bid For Mallory Planned," *New York Times*, 10 Nov. 1978, D5. By the 1990s, Duracell was the acknowledged leader in consumer batteries: "Duracell International, Inc. is the world's largest manufacturer and marketer of alkaline batteries. . . . Duracell International markets the brand Duracell, under the same name, around the world, and controls 79 percent of the U.S. consumer battery market." See John A. Sarich, "Duracell International Inc.," in *International Directory of Company Histories*, ed. Paula Kepos, 85 vols. (Detroit, 1988-2007), 9: 179-81, quotation at p. 179.

[35] Mallory, *Recollections*, 142. Ruben himself also noted that the proximity of the Tarrytown lab "allowed us to have regular meetings with their staff on the sealed mercuric oxide or manganese oxide alkaline battery to develop new applications." See Ruben, *Necessity's Children*, 122.

> an individual can survive and be great in spite of big science, big engineering, and big industry.[36]

Piore, with a doctorate in physics and director of IBM's expansive research operations, represented one end of the innovation spectrum; Ruben, the independent inventor, represented the other. Mallory's mixed innovation strategy occupied a position somewhere in the middle, embodied in its long-term relationship with Ruben and in its industrial laboratory dedicated in his honor.

## Conclusion

In conclusion, I stress three themes that emerge from the case of inventor Samuel Ruben and his licensee, the P. R. Mallory Company. First, this case challenges the prevailing interpretation that, by the early twentieth century, corporate industrial research had supplanted independent inventors. True, men such as Samuel Ruben, Paul Ware, and Fred Hooven were not heroic figures in the Edisonian image, but they were a crucial part of Mallory's innovation strategy, and they were responsible for many of the firm's key products. This case and the historical patent record show that the independent inventor was still alive and well in the twentieth century.

Second, this case helps us understand how inventors and firms worked together in an era of burgeoning R&D. Independent inventors were less entrepreneurial, preferring instead to concentrate on invention, license their patents, collect royalties, and earn a steady income by consulting with a number of companies, even direct competitors. Meanwhile, medium-sized firms such as P. R. Mallory avoided certain fixed costs by outsourcing some innovations, but mitigated the associated risks of a capricious invention market by forming long-term, cooperative relationships with inventors such as Ruben.

Third, this case highlights the variety of ways that firms could organize the enterprise for innovation. In Mallory's hybrid strategy, the firm worked with outside inventors while simultaneously investing in its own vertically integrated research labs. For Mallory, the institutional locus of invention resided both inside and outside the firm. In this sense, I am sympathetic to Philip Scranton's views on production, while extending them into the realm of innovation. Scranton has shown that integrated mass production was not the only way to make goods in the twentieth century; analogously, I suggest that an integrated industrial research lab was not the only way to invent them. Like Scranton, my sense is that, with innovation as in production, there are "multiple paths to industrial profit."[37]

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[36] Emanuel Piore, "The Independent Inventor in the Contemporary World," a speech delivered at the dedication of the Engineering Laboratories of the Mallory Battery Company, Tarrytown, New York, 16 Oct. 1963. Quoted in Ruben, *Necessity's Children*, 141-42.

[37] Scranton has described what he calls "bridge firms," companies such as General Electric and Westinghouse that simultaneously mass-produced staple goods like

light bulbs while custom-producing specialty items like large electrical generators. Just as Scranton's bridge firms simultaneously pursued two production strategies, the P. R. Mallory Company concurrently pursued two innovation strategies; see chap. 9, "Back East: The Electrical Equipment Industry," in Philip Scranton, *Endless Novelty: Specialty Production and American Industrialization, 1865-1925* (Princeton, N.J., 1998), quotation on "multiple paths" at p. 9.