Working Paper 24-027

Coordinated R&D Programs and the Creation of New Industries

Daniel P. Gross
Maria P. Roche

Harvard Business School

Coordinated R&D Programs and the Creation of New Industries

Daniel P. Gross
Duke University

Maria P. Roche
Harvard Business School

Working Paper 24-027

Funding for this research was provided in part by Harvard Business School.

Coordinated R&D Programs and the Creation of New Industries*

Daniel P. Gross†
Duke University
and NBER

Maria P. Roche‡
Harvard Business School

April 2023

Abstract: Government R&D programs have a long history in supporting industry development, yet their impacts are often overlooked in strategy research. We examine how a large, coordinated, government-funded effort to develop radar in World War II spawned a new high-tech industry. Led by an organization stood up to conduct and manage radar R&D—the MIT Radiation Laboratory—it brought together researchers and firms without previous collaborative ties, who were otherwise unlikely to work together, into a temporary cooperative enterprise that rapidly advanced technology and connected R&D to manufacturing and the battlefield. This effort set the building blocks of the nascent postwar radar industry: new technical knowledge, human capital, manufacturing capacity, and demand. The urgency of war, and coordinated investment, accelerated industry incubation from decades to under five years.

JEL Classification: O31, O33, O38, N42, N72

Keywords: Government R&D programs; Mission-driven R&D; Technology management; Technology policy; Industry emergence

*First and foremost, we wish to thank Bhaven Sampat for his collaboration in the early stages of this paper and feedback throughout this project. We also thank Rajshree Agarwal, JP Eggers, Stine Grodal, Josh Krieger, Mahka Moeen, and Tiona Zuzul, and especially discussant Steve Usselman, as well as audiences at the NYU Stern Economics & Strategy conference, the Georgia Tech REER conference, and the HBS Entrepreneurial Management faculty brown-bag for comments. We also thank Deborah Douglas at the MIT Museum and Jeremy Kepner at Lincoln Laboratory for helpful discussions, and Innessa Colaiacovo, Jack Edmondson, and Riley Choe for research assistance. We are grateful to Duke University's Fuqua School of Business, the HBS Division of Research and Faculty Development, and the NBER Innovation Policy grant for financial support. This material is based upon work supported by the National Science Foundation under Grant No. 1951470. All errors are our own.

†Address: Duke University Fuqua School of Business, Durham, NC 27708, USA; email: daniel.gross@duke.edu.

‡Address: Harvard Business School, Boston, MA 02163, USA; email: mroche@hbs.edu.

In the fall of 1940, as London was under German aerial attack in World War II, a British delegation arrived in the U.S. seeking technical assistance in developing air defenses (Baxter 1946). Within days, the U.S. government established a new radar development program, which within four months had created and demonstrated the first working prototype microwave radar system. By the time the war ended in fall 1945, radar had developed into a versatile dual-use technology, not only critical to military strategy but also with a growing civilian market and a blossoming manufacturing industry—despite that the technology was less than five years old.

A central question in strategic management is what triggers the formation of new industries (e.g., Agarwal et al. 2017, Moeen and Agarwal 2017). Though the industry studies literature typically emphasizes market-led development, many important high-tech industries of the past century developed with government support (Nelson 1982). The paradigm behind modern research policy, for example, has government agencies funding the creation of basic knowledge as a public good, but leaves it to the market to find ways to use it—such as in biotechnology (Zucker et al. 1998). In this paper, we study a different model: focused government R&D programs, funded by mission agencies, which develop radical new technologies to address specific needs and create integrated ecosystems around them (Mazzucato 2018, Azoulay et al. 2019). History offers many examples, from nuclear energy, to antibiotics, to satellite navigation, to mRNA vaccines. Though industry development is typically incidental to the policy goal, these programs have often laid the groundwork for new commercial industries to emerge around the technology they yield.

With this paper, we ask how and why: how do coordinated, government-led R&D programs breed new high-tech industries—and when and why are they able to quickly bring new industries to the brink of commercialization? We explore these questions through a case study of the World War II development of microwave radar and the postwar emergence of a radar industry. Propelled by the urgency of war, the radar program not only produced significant advances in a new critical technology that shaped the war's outcome: it also established the primordial technical knowledge, trained up R&D workforce, manufacturing capabilities, and early adoption for postwar commercial activity. Perhaps most distinctively, this initial development took place largely within the boundaries of one organization—what might be called a 'cradle of industrialization'. Figure 1 shows the speed and scale of its effect: despite being an infant technology in 1940, the microwave radar industry grew from a null set to nearly 200 firms in just the first postwar decade.

< Insert Figure 1 about here >

The analysis in this paper first requires institutional context. The U.S. radar program traces its beginnings to June 1940, when President Roosevelt created a National Defense Research Committee (NDRC; later subsumed into the Office of Scientific Research and Development, or OSRD) to put civilian scientists to work on military R&D problems. One of NDRC's priorities throughout the war was radar, and at the heart of the wartime radar effort was the MIT Radiation Laboratory: a novel enterprise stood up in World War II to lead and perform U.S. radar R&D, in one of the first instances of "big science" being turned to large, applied problems.

With no strong U.S. precedent for a large, interdisciplinary, cross-institutional R&D program, the Rad Lab was, for its time, an experiment in collaboration, drawing researchers from around the U.S. to work on radar engineering—an infant subject new to nearly all of its staff—and working closely with the military and manufacturers to understand problems in the field and produce radar systems at scale. Launched in late 1940 with a nucleus of three dozen physicists, it grew to a staff of nearly 4,000 by the end of the war. Its R&D expanded from experimental rooftop radar sets to land, sea, and airborne systems; radar-driven automatic anti-aircraft artillery; radar countermeasures; and more. As it grew, it spun out offshoot labs to other universities; opened a branch office in England; established field operations; hosted military and manufacturer liaisons to collaborate on priorities, designs, and handoffs; and even trained radar operators.

This R&D sprint continued until the end of the war in 1945, delivering major advances in radar that were instrumental to its outcome (Baxter 1946). When the war ended, however, the Rad Lab was unwound. Its staff dispersed widely to government, industry, and the academy. The technical knowledge it had produced in secrecy was published. Military demand for radar persisted into the postwar era, and civilian demand began to grow. Many wartime suppliers continued serving this demand, and adjacent firms began to enter the expanding market.

The radar program achieved in years a scale of industry development that in other contexts takes decades (Agarwal and Bayus 2002, Golder et al. 2009): as the Rad Lab house historian later wrote, "25 years of change were telescoped into five" (Guerlac 1987). Our question is how. Using a mix of empirical and qualitative evidence, we show that although the Rad Lab was temporary by design, it developed several critical inputs to a postwar industry take-off. These include: a massive amount of technical knowledge in microwave engineering, a wide array of radar systems, and a highly-trained research corps that could continue postwar radar development. The broader effort added more: its manufacturers developed engineering and production capabilities, and military and experimental applications of radar identified a broad range of civilian use cases.

After the war ended, civilian radar diffused quickly, while military demand grew in both existing applications (land, sea, and airborne radar) and new ones (e.g., guided missiles and missile defense). Many of the top firms which supplied this demand were leading World War II radar suppliers, but the technical base the Rad Lab developed enabled wider entry. Supporting this emergent industry was a postwar network of industrial and military R&D laboratories, many of which staffed up with Rad Lab alumni. Patent data reveal direct technological continuities: over the first postwar decade, 20-40% of firms patenting in radar each year cited Rad Lab patents or technical publications, and 10% listed a former Rad Lab researcher as an in-house inventor.

We use this to bring into focus a structured framework for understanding how coordinated R&D programs can give rise to new industries. This framework is related in spirit to the recent work of Agarwal et al. (2021), though we use the detailed evidence and accounts in this paper to bring into relief insights from this historical example (Argyres et al. 2020). The World War II effort fostered four fundamental high-tech industry building blocks: 1) new technical knowledge, 2) human capital to drive further technological development, 3) manufacturing capacity and supplier networks, and 4) an anchor customer. We argue all four pieces were required for the radar industry to flourish in the postwar era, and that the Rad Lab additionally played a key role in connecting them with each other. In effect, these investments sunk the fixed cost of initial R&D, workforce development, and capacity-building, and reduced technological and commercial uncertainty by getting the technology working and into practice and establishing lead users and uses.

Conceptually, we add to existing research on industry evolution in two ways. First, we demonstrate how coordinated technology development programs can be primogenitors of new technology-based industries, fusing an end-to-end range of industry building blocks from R&D to manufacturing and diffusion (Zilberman et al. 2022), and we explain when and why these settings can be fertile ground for industry development. Second, we highlight a role that academic organizations can play in providing both the human capital and infrastructure to support these programs, especially when they operate at the boundary of basic science and applications. In doing so, we build on research studying the productivity of such "hybrid" scientists (e.g., Dietz and Bozeman 2005), impacts of collaborative research (Katz and Martin 1997), and advantages of physical co-location for fostering collaborative R&D and knowledge spillovers (Roche et al. 2022).

The radar example is characteristic of a wider range of technologies that developed with government support which funded R&D, coordinated early industry actors, and created an initial market. This set includes nuclear energy, high-performance computing, space systems, satellite communications, semiconductors, photovoltaics, and more. The Rad Lab itself is similar to modern institutions which develop ecosystems around emerging technologies through cross-sector collaborative R&D projects, such as the U.S. Defense Advanced Research Projects Agency (DARPA), or Lincoln Laboratory—a large, federally-funded R&D organization administered by MIT that works on defense technology but has also spun out over one hundred startups since its founding. As a paradigmatic example—quite literally, the model off which later programs were designed—we believe it valuable to engage in a deeper study of the World War II episode.[1] Recent events such as the COVID-19 pandemic have reinforced the modern relevance of these questions as well.

We proceed as follows. Section 1 provides a conceptual foundation for the paper. Section 2 reviews the history of the World War II radar R&D program, and Section 3 documents the emergent postwar radar industry. In Section 4 we use narrative and empirical evidence to draw links between them. In Section 5, we then synthesize our findings into a framework characterizing how coordinated R&D programs support industry emergence, and explore extensions and boundary conditions. Section 6 offers concluding discussion and poses questions for future study.

[1] Bonvillian (2018) has described DARPA as having inherited the Rad Lab's organizational model, with a "collaborative, flat" structure joining "research, development, and prototyping ... to initial production." Lincoln Laboratory, created in 1951, is directly descended from the Rad Lab. In an interview, the founder of one center at the Lincoln Laboratory described the Lincoln Laboratory to us as "Rad Lab 2.0" and explained that the Rad Lab is "in our DNA" as much today as in the 1950s. We describe other examples later in the paper.

1 Conceptual Foundations

With industries being one of the predominant units of analysis in strategy (Porter 1980), industry dynamics has been a central theme in strategy scholarship since the beginnings of the field. Seminal contributions have documented industry lifecycles around new products, identifying stages of industry development (Abernathy et al. 1978, Gort and Klepper 1982). Subsequent research more deeply examines dynamics within them (Agarwal and Tripsas 2008).

One stage of the industry lifecycle which has received increasing attention is the pre-commercial incubation stage, where technologies are being developed and markets identified or cultivated, but no products have yet been commercially sold. Prior research often attributes industry emergence—the beginning of this pre-commercial stage—to scientific breakthroughs originating in universities or corporate R&D labs (e.g., Rothaermel and Thursby 2007). Research has also emphasized that entrepreneurs with knowledge of latent, unmet demand can transform this knowledge into commercial opportunity around which new industries subsequently develop (e.g., Shah and Tripsas 2007).[2] As this literature has grown, it has also prompted meta-analysis that provides structured taxonomies of the drivers of industry emergence (e.g., Agarwal et al. 2017).

Perhaps the most consistent, high-level insight of this literature is that industry emergence is not a monolithic phenomenon: it takes different shapes, and follows different paths, in different cases or settings. A second theme is that industry boundaries can be difficult to analytically define, and their boundaries are in practice fuzzy, not always clear to managers, and endogenous to firm choices (e.g., Granqvist et al. 2013). Frameworks can still be useful guides for organizing thought, but this heterogeneity, coupled with continuity in the underlying state space, implies they will necessarily have limitations and gaps—one of which motivates this paper.

[2]Examples of industries originating in scientific discoveries include agricultural biotechnology (Moeen 2017, Moeen and Agarwal 2017, Moeen and Mitchell 2020), fiber optics (Cattani 2006), solid-state lighting (Sanderson and Simons 2014), lasers (Suh 2022), and personal genomics (Gao and McDonald 2022). Examples where firms or entrepreneurs identified, and tailored to, unmet demand include typesetting (Tripsas 2008), scanning probe microscopy (Mody 2006), motorsports (Aversa et al. 2020) and sports equipment (Baldwin et al. 2006).

1.1 Industry emergence and R&D policy

A common theme across these examples is the emphasis on market-led industry development. The impact of policy has received less attention, and when it does, the focus is often on how regulation impedes entry, via its effects on entry costs or profitability (e.g., Dobbin and Dowd 1997, Jacobides 2005, Sine et al. 2005). Paradoxically, however, many of the most important high-tech industries of the last century—from commercial aircraft to computers and electronics—have developed with significant government support, whose form has ranged from explicit subsidies to coordinating mechanisms like government-led industry consortia (see Nelson (1982) for examples).[3] A recurring domain for industry studies research, for example, is biotechnology (e.g., Zucker et al. 1998), where therapies, devices, and drug classes emerge around advances in biomedical science, often funded by the U.S. National Institutes of Health (NIH) (McMillan et al. 2000).[4]

The rationale for public R&D subsidies has been widely recognized since Nelson (1959) and Arrow (1962). The Nelson-Arrow paradigm emphasizes several issues which may depress private R&D—and in turn challenge market-led industry development—including fixed costs, appropriability, and uncertainty (e.g., technical or demand uncertainty; see Agarwal et al. 2017). These challenges are thought to be particularly acute for fundamental research without direct commercial applications, a view which motivates the emphasis of civilian U.S. research policy on funding basic science, through agencies like the NIH or the National Science Foundation (NSF).

Push vs. pull mechanisms and "mission" policy

A salient gap in this literature, by our reading, is around a distinct but historically important originator of new industries: coordinated, government-led technology development programs. Whereas other policies that support innovation (e.g., basic research funding or R&D tax credits) are technology-neutral and diffuse, and designed to "pull" commercial R&D investment, government R&D programs push new technology to address specific needs of their sponsors and are explicitly use-oriented, focused, and actively-managed (Mazzucato 2018, Azoulay et al. 2019). Though "mis-

[3]A full list of technologies and industries which benefited from direct government activity, by our counting, would run into the dozens. Aircraft, computers, communications, electronics, nuclear energy, synthetic materials, drugs, and medical devices are all areas where public investment has supported industrial development.

[4]As Alic et al. (1992) have explained: "The early U.S. lead in biotechnology ... is almost entirely due to research in fundamental molecular biology and biochemistry, primarily supported by NIH."

sion" R&D approaches have a long history (especially in the defense sector) and are increasingly advocated for a wider range of problems (e.g., Mazzucato 2021), their intersections with strategy have traditionally not been a significant focus of scholarly attention.

There are, however, exceptions: recognizing that mission-driven R&D programs may be a distinct engine of technology-based industries, Agarwal et al. (2021) extend the industry emergence literature to mission-oriented grand challenges, defined by the authors as complex social problems which require innovation to resolve—even citing World War II radar development as an example. We find it useful to draw a distinction between "missions" (or mission-oriented policy) and grand challenges. Whereas a grand challenge is a problem statement with a call to action, a mission is a solution method: a centrally-led, coordinated attack. Our emphasis in this paper is the latter: R&D programs with specific objectives (Foray et al. 2012). There are multiple views of the mechanisms of action for commercial impacts, but they converge on an idea that missions can overcome key bottlenecks to commercial development (George et al. 2016).

The potential bottlenecks for high-tech industries are many. These can include requisite basic and applied research, the creation of embryonic products and prototypes, manufacturing capabilities, and market development. Each of these hurdles typically requires significant time and investment to surmount: pre-commercial technical development has been shown to last on average 26 to 28 years in technology-intensive industries (Agarwal and Bayus 2002, Golder et al. 2009). In the face of these costs, it is perhaps unsurprising that some firms ally in the incubation stage—through joint ventures, acquisitions, or industry associations—to co-develop shared or complementary assets (e.g., Rothaermel and Thursby 2007, Moeen and Mitchell 2020).

1.2 Interactions with collaborative R&D models

This paper also intersects with research on collaborative R&D models, and the operation of academic organizations on the boundary of basic science and applications. Once billed as "the greatest cooperative research establishment in ... the world" (MIT president Karl Compton, quoted in Saad 1990), the Rad Lab presented a new model for university-government-industry collaboration. A systematic examination of how its organizational choices affected its performance is a worthy subject for further research. As is, its example highlights the role that universities can play in fostering multidisciplinary, cross-sectoral collaborations for mission-oriented R&D projects, and especially in coordinating industry participants around emerging technologies.

A specific role that academic institutions played in this case was in providing the infrastructure to support large central laboratories and attract elite scientists and students to work at them. This includes lab space itself (e.g., MIT's infamous Building 20). Centralization can be advantageous to R&D productivity, particular when knowledge is internally sourced and there are large interdependencies in knowledge production (e.g., Argyres and Silverman 2004, Grigoriou and Rothaermel 2017, Eklund 2022). When transfers of complex knowledge and skills require close interaction, and knowledge flows degrade over short distances (Roche et al. 2022), an effective way to organize research can be the laboratory model (Roche 2023). The Rad Lab, however, represents a distinct mode of organizing R&D than academic labs: larger, more applied, more intellectually diverse, and structurally integrated with suppliers, manufacturers, and users.

2 Historical Background

World War II began in September 1939 with Germany's invasion of Poland and quickly spiraled into a conflagration igniting most of Europe. Though the U.S. was largely on the sidelines, by the spring it was becoming apparent it may be drawn in. Worried that the military was "pathetically unprepared" to fight a modern technological war (Stewart 1948), a small group of high-ranking science administrators—led by Vannevar Bush—approached President Roosevelt with a proposal to put civilian scientists to work on military problems. A meeting with Roosevelt in June 1940 led to the creation of a National Defense Research Committee (NDRC), later subsumed by the Office of Scientific Research and Development (OSRD). Over the next five years, OSRD grew to be a major force in the war effort, organizing and funding thousands of research projects which developed new technologies and medical treatments in support of the Allied forces.

Radar was a priority from NDRC's beginning. Research in the 1930s at the Naval Research Laboratory (NRL) and Army Signal Corps, as well as by the British Air Ministry, had found that radio waves could be propagated, reflect off distant objects, and return, and these signals could be used to locate enemy vessels and aircraft and track movement.[5] These early efforts at radio detection

[5]Much of the groundwork for the research of the 1930s was laid by experiments on electromagnetic radiation conducted

were independent of each other and based in the high and ultra-high frequency (UHF) range of the electromagnetic spectrum (Baxter 1946). U.S. efforts progressed at a relatively slow pace before the war, with meager funding and limited impetus, though the British were somewhat more focused, given their proximity to (and as a result, threat of) German attack.

As the war began, Germany quickly established air supremacy in its invasions of Poland and France and later the London Blitz. Its success in these campaigns made clear that aerial warfare would be fundamental to World War II military strategy, which necessitated the ability not only to track enemy craft, but also to see through fog or darkness—abilities which only radar could deliver. On both sides of the Atlantic, however, UHF radio detection had severe limits in its range, accuracy, resolution, and sensitivity. The microwave range of the spectrum (wavelengths <10 cm) held more promise for technical performance, but as of 1940, there was no technology which could generate microwaves with enough power for any practical radar application.

Into these circumstances NDRC was born. Research into UHF frequencies and pulse transmissions (i.e., refinement of existing technique) were among its first requests from the U.S. Army and Navy (Baxter 1946). Responsive to this priority, NDRC immediately appointed a committee to study the problem, which recommended an emphasis on microwaves, but without resolving how. The answer arrived September 1940, on a British technical mission to the U.S. led by Sir Henry Tizard (an influential British defense scientist). Among the technology brought by the Tizard Mission was the cavity magnetron, a device invented by British scientists only months earlier which was the first vacuum tube that could generate microwaves with enough power for use in radar—"an intensity some thousand times as great as the most advanced American tubes" (Kevles 1977). NDRC did not yet have a radar development program, but the British urgently needed help developing radar to support its defense against German night bombing, and NDRC agreed to take on the project of developing the magnetron into an airborne intercept radar system.

Conferencing with the British visitors until mid-October, NDRC members determined this would be a project of significant scope and scale, and that it would operate most effectively under a central laboratory model in the spirit of similar laboratories in Britain, staffed with civilian scientists and

by German physicist Heinrich Hertz during the late 1880s (Skolnik 2022).

engineers from universities and industry.[6] After a brief search, it chose to site the laboratory at MIT. The chosen name was the "Radiation Laboratory" (colloquially, the "Rad Lab"). On October 16, Lee A. DuBridge, a physicist at the University of Rochester, was appointed its director at the recommendation of Ernest O. Lawrence (who was a member of the committee advising NDRC on the microwave problem), and he and other NDRC members began tapping their networks for recruits. By late October, the Rad Lab's core was in place, drawing primarily from the academic physics community—including several former or future Nobel laureates.

The Rad Lab's first meeting was held on November 11, 1940, to a room of roughly three dozen staff members. What is most striking is their near-absolute lack of specific knowledge on the problem: DuBridge, quoted in Zachary (1997), described, "They knew little to nothing about the microwave electronics that would be needed to translate the British 10-centimeter magnetron into a working radar system." DuBridge described these early weeks as a "blitz": there was an immediate need to deliver proof of concept to build confidence with the Rad Lab's patrons, but not even a basic understanding of how the magnetron worked. Fundamental understanding was a first-order concern. Second was engineering and demonstration. By January, it had jury-rigged a radar system on an MIT rooftop that could detect buildings across the Charles River, and on February 7 it successfully tracked an airplane taking off from Boston's Municipal Airport.

The initial goal of this R&D had been to produce an airborne radar set for British fighter plan, but the Rad Lab's work soon blossomed to other types of radar systems, including air-to-surface radar and automatic, radar-driven anti-aircraft artillery. The Lab itself grew along with it, and staff began to pour in from around the country, especially physicists and electrical engineers, from both universities and industry—but also business staff, support staff, representatives from the Rad Lab's industry partners and the military, and others.[7] The attack on Pearl Harbor on December 7, 1941, and America's formal entry into the war on December 8, dramatically increased the stakes of its work, and cemented its place in the war effort. By the end of the year, the Lab had transformed

[6] Britain had been conducting radar R&D at its Telecommunications Research Establishment (TRE) since the mid-1930s, which offered an organizational precedent for the U.S. program—though it faced several distinct challenges, including direct exposure to the war, frequent location changes, and a less robust domestic manufacturing sector for production at scale, which moderated its impact relative to the U.S. program. The Rad Lab and TRE nevertheless collaborated throughout the war, including through staff exchanges and information sharing. Britain, for example, was an important source of data on German radar for R&D in countermeasures.

[7] Although "the nucleus [sic] of the Laboratory was a group of nuclear physicists... [it] hired everything from airplane pilots to ballet dancers" (Massachusetts Institute of Technology 1946).

from a startup hacking together experimental radar kits (e.g., see Appendix Figures A.1 and A.3) to a large and rapidly growing organization of nearly 500 staff.

Pearl Harbor marked a new phase in a sprint that would last for most of the rest of the war. In 1942, the Rad Lab formally reorganized into twelve divisions, each comprised of narrower working groups (Appendix Tables A.1 and A.2). It added field stations for testing, hired staff to assist with transitions to manufacturing, increasingly hosted more liaisons from its customers in the armed services, and even produced spinouts such as the Columbia Radiation Laboratory and the Harvard Radio Research Laboratory (RRL), which led research on radar countermeasures. Industrial contractors like Western Electric, GE, RCA, Sperry Gyroscope, and Raytheon supplied components and did most of the manufacturing to fulfill military orders of Rad Lab-designed radar, though the Rad Lab also provided limited crash production. By the end of 1943, it employed nearly 3,000 people, later peaking at nearly 4,000. Among its technical staff were "350 from industry, and about 1,050 from universities, including 353 professors and instructors, 421 holders of PhDs or other graduate degrees, and 266 science students" (Massachusetts Institute of Technology 1946). The RRL at Harvard itself had 800 people, with roughly 200 researchers.

Throughout this time, the Rad Lab operated with wide latitude and significant funding from OSRD, which by the end of the war had spent over $100 million on the Rad Lab alone, and over $150 million on radar and countermeasures R&D overall ($2.5 billion today). Manufacturers began to send their own personnel to Cambridge for training and to collaborate on prototypes, and because the Rad Lab had over 100 subcontractors, "this type of liaison came to constitute a large and increasing part of its activity" (Baxter 1946). To support adoption, it embedded staff in the military, including in the battlefield. The RRL did the same. Because radar itself was "relatively new and virtually unheard-of" prior to the war, it led "informal courses and lectures" for staffers (Harvard University 1946), and formal training classes instructing military servicemen on how to use Rad Lab-designed radar equipment (Massachusetts Institute of Technology 1946).

By 1944, the tide of the war had begun to break. Germany surrendered roughly a year later, on May 7, 1945, and Japan on August 14. That day, the Rad Lab's leadership triggered its termination plans. Priorities included getting patents filed, cataloguing its discoveries, and finding jobs for its staff. A new Office of Publications led the preparation of "manuscripts summarizing the engineering and scientific advances resulting from the work on radar" (Massachusetts Institute of Technology 1946), resulting in the Radiation Laboratory series, a set of 27 technical volumes spanning the full range of subjects in microwave engineering, which became an "occupational bible" for physicists or engineers studying microwave electronics (Buderi 1996). In addition, the Rad Lab and RRL filed nearly 2,500 formal inventions. Researchers dispersed widely, including to industry, faculty jobs, graduate school, and the military (Appendix Table C.2).

3 Postwar Industry Takeoff

After the war ended, radar hit the mainstream (Buderi 1996). Military demand continued growing as radar became a critical defense technology in the Cold War and its applications expanded into guided missiles and air defense systems. The technology also spread to the civilian sector, where a commercial market took off. This growth was largely driven by the diffusion of military applications into civil aviation and maritime navigation. Radar was used in ground-controlled approach (GCA) aircraft landing systems and Rad Lab-designed long-range navigation systems (LORAN), which were used to guide civilian marine traffic around much of the world. Growth in civilian radar was also propelled by postwar development of serendipitous wartime discoveries like weather detection and radio astronomy, which generated additional, specialized demand. Leading the charge in the commercial market were several of the major wartime radar firms.[8]

Three sources of data help us draw the link from the World War II to the postwar era. We use data from Guerlac (1987)'s administrative history of radar in World War II, as well as data on military supply contracts (Li and Koustas 2019), to identify wartime suppliers of radar components and systems.[9] We collect analogous, postwar data from Vietnam War-era military prime contract files,

[8] As Buderi (1996) writes, "Companies like Raytheon, AT&T, Westinghouse, RCA, General Electric, and Sperry kept on producing military sets for planes, ships, early warning systems, and even guided missiles." Many of these firms also "scurried to build radars for [civilian] ships and fishing boats" and for civilian aircraft, adapting military designs to these applications. The applications of microwave engineering went further: "Radar was also the driving force behind [the] microwave communications and video revolution ... pushing the radio spectrum to shorter wavelengths opened up more than two hundred times as many channels for radio communication as existed before the conflict ... then came huge improvements in transmitters, receivers, and everything in between. Months after the war ended, wartime radar manufacturer Philco had filed plans with the Federal Communications Commission to establish a microwave television network ... RCA [had] announced plans for a TV network of its own ... and Raytheon sought approval to build a nationwide microwave communications web."

[9] According to data from Li and Koustas (2019), who provided a custom extract filtering war supply contracts to those with "RADAR" in the product description, between 1942 and 1945, the U.S. military procured over \$12 billion (2022 dollars) of radar equipment across 250 production contracts with 75 suppliers. These totals likely undercount the

which provide records of the universe of U.S. defense contracts, and filter these data to radar supply codes.[10] Finally, the Thomas Register of American Manufacturers (TRAM) provides insight into the development of the commercial market. The Thomas Register has been widely used in research on industry evolution (e.g., Gort and Klepper 1982, Klepper and Graddy 1990, Agarwal and Gort 1996, Agarwal and Bayus 2002). "Radar" first appears in TRAM in 1944, though the firm listing is suppressed to limit wartime disclosure. The first firm listing is provided in 1947, and updated in triennial editions thereafter. We collect data on all firms from the 1947 to 1956 editions, which we manually crosswalk to the firm-level military contract data.

Evidence of continuity from the war to the postwar era is visible in the data. We find one quarter of World War II radar equipment suppliers in the Thomas Register, representing 50% of contract value, including six of the top 10 firms, which are listed in Table 1. Many of these firms remained major military suppliers of radar into the 1960s as well.

< Insert Table 1 about here >

Yet the Rad Lab also opened a door for wider entry. Table 2 describes the structure of the industry as it developed over the first postwar decade, and presents several notable patterns. First, whereas incumbent firms and wartime suppliers comprised a sizable fraction of the industry in its first few years, it was increasingly populated by new and less R&D-intensive firms over time, which could exploit the advanced state of the art, and its commercial opportunities, rather than developing new technology wholesale. Second, despite a more than tripling of firms in the Thomas Register between 1947 to 1956 (from 53 to 171), the firm size distribution remained relatively stable and uniform. Third, the industry was heavily geographically concentrated in New York City and the surrounding region, which was home to roughly half of all firms in the Thomas Register, with the next-largest clusters (Chicago, Boston) being one-tenth its size.

< Insert Table 2 about here >

total value, though not the set of suppliers, as Guerlac (1987) describes "more than 70" prime contractors supplying roughly $50 billion (2022 dollars) of radar equipment.

[10] The source data are Department of Defense (DOD) Military Prime Contract Files for FY 1966 to 1975, available for download from the U.S. National Archives and Research Administration. Our focal supply codes are for "Radar Equipment, Airborne" and "Radar Equipment, Except Airborne". Over this period, the U.S. military procured $29 billion (2022 dollars) of radar equipment from nearly 1,000 suppliers.

Competitors in the new industry appear to have made use of several resources which the Rad Lab, and wider World War II effort, produced. The Rad Lab Series was an essential reference for firms entering the industry. In some cases, Rad Lab alumni were as well. Lab records show that staffers dispersed widely after the war, and roughly half of those with known placement outcomes entered industry—including dozens to postwar radar manufacturers (Appendix Table C.2). These alumni brought with them not only their technical know-how, but also experience with the Rad Lab mode of operation. Buderi (1996) characterizes these staffers as "a hybrid scientist, capable not only of probing nature's mysteries, but of building the equipment for the job," operating under distinct paradigms from uni-disciplinary physical scientists or engineers.

Supporting the growing industry was continued research and development. After the war ended, the radar research program was replaced by a more diffuse, nationwide R&D network, comprised of a wide range of institutions. The Army, Navy, and Air Force each supported R&D in radar systems (through the Army Signal Corps Laboratory; the Naval Research Laboratory; the Air Force's Cambridge Research Center and Lincoln Laboratory; and more). Bell Labs continued research into radar and microwave engineering, and several manufacturers had in-house R&D programs (catalogued in postwar editions of the National Research Council's "Industrial Research Laboratories of the United States"). Universities partook as well, in some cases using surplus Rad Lab equipment, which was dispersed across a handful of academic institutions. The Rad Lab itself was reconstituted into MIT's Research Laboratory for Electronics, which initially employed over two dozen former Rad Lab staff, and inspired the creation of Lincoln Laboratory.

Radar technology evolved significantly in the postwar era, opening up further military and commercial potential. Its continued development is plainly visible in the patent record: Figure 2 plots the time series of annual radar patents (solid blue line; here measured narrowly, but precisely, as patents with 'radar' as a keyword, though patterns are similar for broader, class-based definitions). The figure also demonstrates technological continuities between the Rad Lab and this development, showing that much this growth drew directly on the Rad Lab's work—especially in the crucial years immediately after the war ended. For the first 10 to 15 years after World War II, between 20% and 30% of firms with radar patents in a given year cited Rad Lab patents (dashed red line, measured by the right axis); around 10% cited the Radiation Laboratory series (dash-dot green line); and many of these patents included RL/RRL alumni inventors.[11]

< Insert Figure 2 about here >

4 The Rad Lab as an Incubator

The puzzle of this paper is how the World War II radar program achieved in under five years what typically takes decades: the incubation of a new high-tech industry, and around a technology that did not yet exist when the war began. To evaluate this puzzle, we will examine more closely the distinctive features of the Rad Lab and the wider radar program.

To our knowledge, our analysis will provide the first systematic, empirical evidence on the impacts of the Rad Lab. We complement our findings with qualitative evidence to provide a more complete characterization of its linkage to postwar commercial activity. In studying the technical development of radar, we make use of Rad Lab and RRL archival records from MIT and Harvard, which identify Rad Lab and RRL technical staff, and OSRD records from the U.S. National Archives and Research Administration. We link Rad Lab and RRL inventors and inventions to patent data from a mix of sources including the U.S. Patent and Trademark Office (USPTO) and Google Patents. From these sources we obtain a range of measures—including basic metadata, citations, inventors, assignees, and textual content—for all U.S. patents filed between 1930 and 1960, which comprises our base patent sample. We also draw on narrative sources including oral histories with Rad Lab alumni and postwar histories by Guerlac (1987) and Buderi (1996).

4.1 Data

We use OSRD contract records to measure Rad Lab and RRL invention (see Gross and Sampat 2022a, or Appendix B). These records identify 588 patents produced by the Rad Lab and RRL, comprising roughly 20% of OSRD patenting overall. We supplement these data with information on Rad Lab and RRL research staff from lab records, including backgrounds and job placements. The Rad Lab staff roster contains 1,362 names and covers most of the Rad Lab's research corps: Guerlac (1987) claims the Rad Lab peaked at 1,189 technical staff and employed roughly 1,550

[11] Appendix Figure C.2 provides an analogous chart for "microwave" patents, with similar patterns.

distinct researchers in total. The RRL directory lists 1,043 staff members, but it likely includes more non-technical staff, as RRL was considerably smaller.[12]

We next link these individuals to inventors on U.S. patents from 1930 to 1960. To do so, we first build a dataset of historical patents and inventors (see Appendix B). This work begins with a USPTO master file of granted patents (Marco et al. 2015). We merge in inventor names provided by Berkes (2018), which improve on data available from Google Patents, Derwent Innovation, and other commercial data sources with a fresh OCR of patent documents and significant post-processing and validation. After some additional cleaning, we split inventor names into first names and surnames, based on their relative population frequencies, for linking.[13]

We link Rad Lab and RRL staff members to patent inventors in three ways. First, we identify all inventors on RL/RRL patents, and manually crosswalk them to Rad Lab and RRL staff rosters. We can then apply this crosswalk to the complete patent data, including to non-RL/RRL patents. In our second approach, we work in reverse: we take Rad Lab and RRL roster names and manually search for them in the patent record. In a third approach, we programmatically make links between patent inventors and researchers by matching exactly on first name, last name, and middle initial (where provided). Each approach comes with tradeoffs between precision and recall, and we prioritize precision in making the first approach our preferred one.[14]

Finally, we measure characteristics of individual patents. One such characteristic is novelty, which we measure through text-based and citation-based methods.[15] We additionally identify government-assigned patents, using data from Fleming et al. (2019) with modifications to increase the identi-

[12] Thirty-four individuals appear in the staff lists of both labs, reflecting some labor flows between them.

[13] Inventor names are often provided in the format "last first [middle]", but sometimes appear as "first last". We impute which token is a first name and which is a surname based on their relative frequency as first names and surnames in population-wide data from the Social Security Administration and contemporary censuses. This simple procedure typically makes clear predictions and returns sensible results.

[14] Results throughout the paper are robust to the other approaches to record linking. A distinct challenge in linking these two sources is inventor disambiguation (e.g., Li et al. 2014). In most cases, the names from our lab rosters are sufficiently distinctive that we can make links with high confidence, but common names increase the risk of false links. This measurement error would likely only attenuate our results (i.e., a conservative bias), as it would result in our mixing untreated individuals with treated ones. In robustness checks, we remove individuals with common names from our sample, which we define as those whose first name and surname ranked in the top 100 and 500 of those in the 1940 census, and obtain similar results to those presented below.

[15] We use word embeddings (from Google Patents) to produce a text-based pairwise patent similarity measure, and forward citation data to identify patents which tend to be cited by the same future patents, and are thus likely similar or closely related. For each patent, we calculate its maximal similarity to the existing stock on both of these measures. When this maximal similarity is low, we consider a patent more novel.

fication rate. We also use patent keywords to identify patents that specifically, explicitly relate to radar. Collectively, these measures will be used to study the nature of Rad Lab and RRL inventors' patenting activity before, during, and after the war.

4.2 Analysis

To more fully understand how the radar industry came into being, in this section we more closely examine the wartime R&D effort. We combine empirical and historical analysis, following a growing body of work in the strategy literature (e.g., Tripsas 1997, Braguinsky and Hounshell 2016, Pillai et al. 2020). We first turn our attention to the Rad Lab's quantifiable output, estimating its impact on the generation of new science and technology and development of a technical workforce trained in the art of radar and microwave engineering. We then examine coordination with manufacturers and military users, where we rely on historical accounts and primary evidence from oral histories, which describe upstream and downstream industry participants.

4.2.1 New Science and Technology

World War II transformed radar from a primitive state into a powerful, versatile set of technologies. The Rad Lab designed almost half of all radar sets deployed in World War II, created over 100 different radar systems, and helped produce over a million magnetrons (Saad 1990). Table 3 provides an empirical view of its output, as reflected in its patents. The table lists the top 10 patent classes with RL/RRL patents, illustrating their concentration in radio wave systems, and suggesting a material role in advancing this field: the Rad Lab and RRL were among the top producers of the hundreds of patents in these classes in the mid 1940s.

< Insert Table 3 about here >

The inventions that the Rad Lab and RRL produced were also distinctive. Table 4 compares Rad Lab and RRL patents to others in the same classes and filing years. We first evaluate novelty, measuring the maximal similarity of each wartime patent to the pre-war patent stock, and comparing that of RL/RRL patents to contemporary patents in the same classes. We do so with both text- and citation-based similarity. To simplify interpretation we standardize units. Columns (1) and (2) indicate that RL/RRL patents were 0.15-0.2 standard deviations less similar to the pre-war patent stock (that is, more novel) than others in the same classes and years. RL/RRL patents were also more likely to be collaborative (Column 3) and were subsequently more heavily-cited relative to contemporaries (Columns 4 to 7). The magnitudes of these differences are large enough to be economically meaningful: RL/RRL patents were roughly 30% more likely to involve multiple inventors (against the mean) and 20% more heavily-cited.

< Insert Table 4 about here >

This evidence matches contemporary perspectives, including official historians (Baxter 1946, Guerlac 1987). The Rad Lab yearbook describes its work as follows:

> Its researches, begun as a gamble, had in 4 years made obsolete nearly all other radars... It went farther, certainly, than the immediate 'excess profits' of OSRD's investment—the things that almost got finished but never quite reached the theatres of action; the multiform airborne radars that would become standard equipment on civil craft; the high-resolution sets that would show the streets and alleys of a city; the high-power stations that would net a nation and show any plane where it stood on the map; the high-flying sets that would catch television beamed from the ground and spray it out over the major portion of the USA; the fire control sets that would protect Navy ships; the phone that would enable a man to talk to any one of a thousand, without wires and without a central switchboard, simply by 'dialing' a wavelength...
>
> It [also] went into techniques. It pushed radio frequencies up to 30,000 megacycles, giving us almost 200 times as many radio communication channels as before. It enabled us to build radio receivers of almost 'ultimate' sensitivity. It made the cathode-ray tube the principal recording and measuring tool in research. It enabled us to measure time-intervals of one thirty-millionth of a second, and thus it opened up avenues of research that were never entered upon before.

Given the depth and breadth of the Rad Lab's inventive step, codifying and disseminating the technical knowledge that was created during the war—but which mostly lived within the Rad Lab and its staff (and to some degree, its partners)—was an important complementary investment. One way it did so was through invention reporting and patents. Even more important than patents was the Radiation Laboratory series: as I. I. Rabi (the Rad Lab's research director) explained, "unless we put [this knowledge] down in the form of books, then after the war, there would only be one group who would know all this technology—the Bell Telephone Laboratories" (I. I. Rabi, as quoted in Buderi 1996). By the numbers, it was widely distributed and impactful: as of July 2022, Google Scholar measured 15,639 academic citations, and Google Patents over 2,000 patent citations, while WorldCat shows hundreds of libraries with circulating copies.

4.2.2 Workforce Development

Technical human capital

Because microwave radar was a new field, there were few people familiar with the science and technology of microwave engineering. One implication is that the Rad Lab might have been a training ground as much as it was an engine of innovation. We show in Tables 5 and 6 that it had lasting effects on Rad Lab researchers' inventive activity. Focusing on a sample of inventors who patented before (1933-1940), during (1941-1948), and after the war (1949-1956), Table 5 examines their propensity to invent in radar-related technology classes over time.

< Insert Table 5 about here >

We estimate difference-in-differences in these propensities for RL/RRL inventors and non-RL/RRL inventors in the pre- to mid-war, mid- to post-war, and pre- to post-war periods. Columns (1) to (3) present intensive measures (the fraction of an inventor's patents in radar classes), and Columns (4) to (6) extensive measures (an indicator for having any radar patents, conditional on patenting at all). We find that RL/RRL staff were far more likely to continue patenting in radar after the war ended, with the magnitude of this effect several multiples of the sample mean. Oral histories suggest similar effects: one Rad Lab researcher recalled "We started [the Rad Lab] program as physicists, looking at things with much more theoretical attention. We quickly found out we had to be practical engineers to make anything work" (Bryant 1991).

In Table 6 we ask whether RL/RRL inventors' postwar invention grew more impactful, as reflected in forward citations. Here our analysis is conducted at the patent level, restricting to patents filed from 1930 to 1939 (pre-war) and 1947 to 1960 (post-war). In Panel (A) we estimate differences in forward citations to pre-war patents of RL/RRL inventors versus others, accounting for class-year fixed effects, and find no statistical differences. In Panel (B), we make this comparison for postwar patents and find much larger, statistically significant differences.

< Insert Table 6 about here >

Managerial human capital

Besides fostering technical human capital, the Rad Lab may have also cultivated managerial talent and teams. The operation of a 4000-person research organization required significant administrative effort: many of its leaders pivoted from research into R&D administration when they joined the Rad Lab, and stayed in it after the war ended. It also gave younger staff experience in interdisciplinary applied research and under the large central laboratory R&D model.

We trace RL/RRL researchers' careers forward via the National Roster of Scientific and Technical Personnel (NRSTP), an NSF-produced census of U.S. scientific workers in the 1960s.[16] We manually crosswalk Rad Lab and RRL staff to the NRSTP, on names and degree information, and use these data to compare their long-run career outcomes to those of peers.

In Table 7, we estimate the likelihood that NRSTP respondents report managerial responsibilities in 1960, comparing RL/RRL alumni to others of the same sector, field, degree level, and years of experience. RL/RRL alumni were approximately 10 p.p. more likely to be in managerial roles—a 35% increase from the mean (Column 1)—and this difference is present in all employment sectors (Columns 2 to 4). These effects are entirely due to an increased propensity to be in R&D management (Columns 5 and 6). The oral history is reinforcing: one Rad Lab electrical engineer later recalled it as having also been a management job (Goldstein 1991b).

< Insert Table 7 about here >

4.2.3 Suppliers and Customers

Manufacturing

The Rad Lab and wider radar program not only conducted R&D but also coordinated the effort to get technology out of the lab and into production and the battlefield. Mobilizing U.S. firms into radar production was an expansive undertaking involving collaboration with scores of manufacturers. Industrial firms performed subcontracted development and engineering, sent liaisons to support R&D and smooth hand-offs, and executed large military orders. Guerlac (1987) describes extensive partnership between the Rad Lab and manufacturers, in which manufacturers' engineers were associated with a Rad Lab project "throughout its course," and Rad Lab researchers "followed it through the manufacturing design and production process."

[16]We describe these data, and the efforts we undertook to prepare them for analysis, in Appendix B.

The success of this effort was not a foregone conclusion: despite an advanced American radio industry, Guerlac (1987) notes that "there were very few companies with the facilities and experience required to carry through a complex new radar system from the laboratory stage to full production." In addition to collaboration and liaison, the Rad Lab had contractual mechanisms to support its industrial partners. These included "educational" orders, which were "primarily intended to assist manufacturers in tooling up for new production," while providing a limited supply of a product for experimental use (Guerlac 1987). The collective evidence describes a system set up to support the rapid development of an industrial base. Over the course of the war, the Rad Lab worked with 70 industrial companies in producing radar for military orders.

The scale of manufacturers' involvement is visible in the value of radar deliveries (available from Guerlac 1987), which grew from $1 billion (2022 dollars) in 1941 to a rate of $20 billion in 1945. The military engaged a wide range of American firms, though production contracts were heavily concentrated in just a handful (Western Electric and General Electric combined for over half of all production contracts by value). These firms' close collaboration with the Rad Lab on R&D and engineering, and experience supplying the military and producing at scale, ostensibly teed them up for the subsequent (postwar) military and civilian markets.

Input Suppliers

Producing radar at scale also required a network of input suppliers. As Guerlac (1987) explains,

> Not only was the radar equipment itself new, but scores of parts and components associated with it were also new—vacuum tubes, electrical circuit components, dielectrics, mechanical parts, and so forth. These were generally manufactured by subcontractors rather than by the prime contractor, and in the microwave field it was one of the Radiation Laboratory's responsibilities to see that all of these component parts were designed and put into production by suitable subcontractors all over the country ...
>
> All [of] this meant that the Radiation Laboratory had to have contact with hundreds of manufacturers [throughout the electronics industry] ... [T]hese manufacturers had to be introduced to the problem; had to train their engineers to develop production methods; had to be supplied with detailed specifications and the necessary test equipment; had to be given initial educational orders to get production under way in advance of larger Army or Navy orders; had to be assisted in the design of special tools; and often even had to develop new methods of packing and shipping.

Organizing the industrial supply chain was thus an (additional) role that the Rad Lab fulfilled to meet the demands of the war. To do so, it needed to coordinate hundreds of electronics firms into producing the full range of components required to design, test, and manufacture radar systems—a significant logistical undertaking, especially against the constraints of war supply shortages. Once developed, however, the wartime supplier network was an industry resource which manufacturers could in principle continue to engage with after the war ended.

The Military Customer

The war also furnished an anchor customer in the military. This demand extended to military suppliers (e.g., aircraft manufacturers) which incorporated radar in their product designs. Military applications proliferated during the war, from locating enemy craft to automatic gunnery, proximity fuzes, guided missiles, and more—including potential civilian applications such as guided takeoff and landing, aerial and marine navigation, and weather prediction.

The implications for a postwar radar industry are many. One was the development of early models which not only demonstrated proof of concept, but were also refined to a state where they were creating significant value in the field. The integration of radar into military strategy and other military technology ensured continued postwar demand from the defense sector, where incumbents' experience and supplier relationships may have locked in initial advantages in the defense sector. A similarly important impact, however, was the introduction of civilian use cases (or dual use cases) supporting the growth of the postwar commercial market.

5 A Structured View of Industry Formation

In many ways, we see echoes of several existing research frameworks and articles in Rad Lab's role in the development of the radar industry. It was triggered by a discovery (the cavity magnetron), unmet military demand, and a grand challenge (Agarwal et al. 2017). Its work reduced commercial uncertainty around technology, demand, and supporting ecosystems (Moeen et al. 2020). Suppliers' postwar pivots from military to civilian markets, and postwar expansions in applications of radar, embodied processes such as domain repurposing (Aversa et al. 2021).

Yet the example is also distinctive. The Rad Lab engaged the full, nascent value chain. Rather than working in isolation, its participants worked in concert: the Rad Lab managed the technological, organizational, and commercial integration that firms would have otherwise had to resolve on their own. It was government-funded, and most of the foundational work was done by non-commercial entities. Most obviously, it took place in the context of a global war.

Building on the insights of prior research, the specific features of the radar example discussed in prior sections, and our own judgment, we introduce a novel framework giving structure to how coordinated R&D programs like the World War II radar project may create a foundation for new industries (Figure 3). We identify four building blocks of a new technology-intensive industry that these programs can contribute: 1) new technical knowledge, 2) human capital, 3) a manufacturing base, and 4) anchor customers and use cases. The radar program, however, did more than establish these building blocks: the Rad Lab also linked them together, raising the odds that the full value of complementarities would be realized as they developed in tandem.

< Insert Figure 3 about here >

5.1 Dissecting the parts

To begin, we reiterate the existing literature's emphasis on new knowledge creation, in both fundamental science and applications. Government R&D programs are organized around specific R&D aims. The Rad Lab, for example, drove rapid knowledge creation in microwave engineering. This concentrated burst of research for wartime military problems significantly advanced the technological frontier, generating large amounts of new understanding, which was then codified, published in patents and book volumes, and distributed widely. The dissemination of this knowledge in turn allowed others to subsequently deepen the science, improve the technology, and apply it to new problems, as evidenced in both scholarly and patent citations.

Equally important, in our view, is a trained research corps which can perform further R&D and manage commercial technology development projects. The Rad Lab created a technical workforce in radar and microwave engineering, in part by attracting new researchers to the subject and in part by deepening existing talent, through both formal training and experience. As we showed in Section 4, many Rad Lab researchers stayed active in the field, making this human capital an industry asset that could outlive the war and was especially valuable for organizations that employed them. The Rad Lab also nurtured managerial talent which could transfer to other contexts. As the Rad Lab's operating model diffused to applied R&D in government and industry, this experience was particularly valuable in settings adopting similar structures.

Research, however, is not enough to sustain an industry, which also needs to be able to produce, and to do so efficiently. The World War II effort stimulated development of manufacturing capabilities across the industry. The Rad Lab performed internal, local prototyping and limited "crash" production, while partnering with large industrial firms on production of Rad Lab-designed parts and systems to fulfill military orders at scale. In this sense, it fulfilled a role that modern government programs sometimes do in establishing complex supplier networks. Common frictions between technology creators and producers such as intellectual property holdups or the 'not invented here syndrome' (Piezunka and Dahlander 2014) were also relieved, due to pressure to deliver quickly and cooperative arrangements like patent pools and technical exchange. The R&D and manufacturing capabilities these firms developed in the war positioned them to be principal suppliers to the military and later the commercial sector in the postwar era.

The final pillar is an anchor customer—in this case, the U.S. military. Close collaboration with users and rapid feedback from the field is valuable for generating knowledge of demand and improving product-market fit. The Rad Lab's collaboration with the military helped it identify new needs and use cases for further R&D, while it concurrently took an active role in training users and supporting implementation. Wartime experience also cultivated an educated user base that had learned to use radar productively in both military and potential civilian applications, feeding sustained demand for radar after the war ended. Also important was the military's willingness to purchase technology at prices above what commercial markets could support, which subsidized manufacturers' progress down the learning curve, to a point where radar could be produced at a commercially-viable cost—a hallmark source of commercial spillovers from government demand seen in several other settings, from semiconductors to supercomputers (e.g. Alic et al. 1992).

We place program management function of the Rad Lab in the middle of this framework, connecting the parts. By our reading, this is a departure from the wider (mainly commercial) industry emergence literature, which often describes the development of individual industry components rather than integrated systems. Yet integrated, cross-functional development is often characteristic of government-led R&D programs, and we think the coordinated nature of the World War II radar effort likely contributed to its success and rapid progress.

5.2 Extensions and limitations

Thus far, this framework presents a static view. We can also consider dynamics, in the form of the sequence of events: in what order do these industry building blocks come together? Success may depend on essential activities being completed on time and in the "right" sequence—though what this means in this case (or others) involves some judgment.

Indeed, in practice, R&D programs are often staged, with dynamic milestones. A specific example from the World War II radar program took the form of early demonstration. On multiple occasions in the winter of 1940-1941, the Rad Lab was days to hours away from being shut down due to a lack of progress in creating a working rooftop radar system that could detect local objects like buildings or airplanes (Baxter 1946). Successful eleventh-hour demonstrations (of buildings, then airplanes) bought time and funding, allowing it to continue.

More broadly, manufacturing requires designs and prototypes, which require R&D, which requires human capital. We see these dependencies broadly reflected in the sequence of the radar program's progression, which began with recruitment and experimental R&D, whereas manufacturers only supplied production orders once prototypes were provided—though these activities also overlapped, and were in practice more mutually-reinforcing than linear.

In many ways, it was the Rad Lab's job to keep these operations running in harmony. Though it appears to have been broadly successful, accounts from those involved indicate that this was not always straightforward. Getting radar technology through bureaucratic obstacles and into military requirements at the Army and Navy was initially difficult—though this was resolved over time (Nebeker 1991). Cooperation between the Rad Lab and parallel efforts at the NRL and Army Signal Corps was hampered by a mix of security measures and turf battles (Nebeker 1991). Rad Lab staff sometimes found it hard to work with researchers at corporate laboratories, who acted as if "they were the professionals dealing with amateurs," even though "there weren't any professionals in the radar field—it was all amateurs" (Goldstein 1991a).

A broader question is whether the radar program would have been successful without the context of war. This is a difficult counterfactual to evaluate, given that it was endogenous to war, but it seems possible it could have been materially harder—e.g., to get Congressional appropriations, coordinate private sector investments, mobilize top talent into military R&D problems, and more. We will return to these limitations in concluding discussion in Section 6, though for now we note that these challenges often surface for modern programs.

5.3 Discussion

To summarize, government R&D programs (like radar in World War II) can shepherd industries' emergence by subsidizing the fixed costs of high-tech industry development (R&D, training, capacity) and reducing both technical uncertainty (through research) and market uncertainty (through guaranteed demand), while underwriting the front end of the nascent industry's learning curve. The path to industry emergence in these cases departs from traditional models of industry incubation in strategy research, highlighting the gap that Figure 3 seeks to fill.

History provides many examples of industries that fit this model. Aforementioned cases like nuclear energy, antibiotics, and mRNA vaccines are among those which most closely match the Rad Lab's example, where urgency also drove an end-to-end range of public investment in R&D, manufacturing, and diffusion (Gross and Sampat 2022b). But many other well-known government technology projects also bear close resemblance, in part if not in full. In writing on Cold War military R&D programs, Alic et al. (1992) make the broader point: "[Although] the Defense Department does not have the mission of fostering new commercial industries," Cold War imperatives provided it "license to pursue pathbreaking technologies, many of which have had important civilian applications" that led to the emergence of new industries around them.

6 Concluding Remarks

With this paper, we have documented how a large, coordinated R&D program in World War II triggered the emergence of the radar industry. We identify four cornerstones of the industry that were cemented, and connected, in war: a new, codified technical knowledge base; a collection of researchers and engineers trained in the art; a set of experienced manufacturers; and established major customers and use cases. Urgency also forced a resolution frictions that in other contexts may interfere with these industry building blocks—from intellectual property protections, to coordinated investment, to persuading customers on new technologies. The result was that the incubation period which in other settings takes decades got compressed to five years.

In documenting this example, we extend the literature on industry emergence to include cases where large, coordinated government investments drive industry development—complementing the work of Agarwal et al. (2021), with a close reading of this formative episode in the history of technology and R&D policy—and we identify how, in this case, it did so. Despite the limitations of historical analogy, we think the modern relevance of this example is material, as mission policy approaches are growing increasingly popular (Mazzucato 2021) and manifesting in policy changes, such as the recent creation of an ARPA-H. This paper provides a fresh view of how and why mission policy has previously borne commercial industries from new technologies.

6.1 Strategy, policy, and "tough tech"

The example may also offer insights for other problems. Radar provides an example of industry incubation that resolved key "tough tech" challenges that many enterprises face today (Lerner and Nanda 2020): fixed costs, uncertainty, and long development timelines can all present obstacles to market-led commercial development. The fixed costs of R&D, training a workforce, engineering prototypes, and developing the government market were sunk by the radar program. Technological uncertainty was relieved with heavy government R&D funding, and demand uncertainty by government procurement. Development timelines accelerated to months, from years and decades. By the end of the war, radar was widely integrated into military operations across the services, and several military applications had proximate value for civilian uses.

These commercial challenges are consistent with the market failure paradigm of Nelson (1959) and Arrow (1962), which posits (in broad terms) that the fixed cost and indivisibility of R&D, uncertainty, and appropriability challenges reduce private R&D investment below socially efficient levels. Although proponents of mission-style approaches (e.g., Mazzucato 2018, Kattel and Mazzucato 2018) draw contrasts between the mission-oriented and market failure perspectives on innovation policy, our paper shows these are not necessarily in tension, as mission-oriented R&D projects can fill gaps in market-led technology and industry development. The consequences for strategy are potentially substantial, as researchers seek explanations for why some industries develop whereas others struggle—and more broadly why some markets are missing.

Notably, however, the World War II radar program was operated to meet an urgent military need in a global war—not to remedy peacetime market failures. One implication is that although the radar program was a technology push investment, it was fundamentally use-oriented and demand-led—a pointed contrast to most of the types of policy interventions contemplated by Arrow (1962) and economists and policymakers since, such as subsidies for pure basic research and R&D tax credits, which are relatively time-insensitive and technology-neutral. A second implication is that commercial impacts were incidental to the primary goal of creating technology for war. That the radar R&D program precipitated the creation of a new industry is thus in part attributable to the dual-use nature of the technology and its potential for spillovers to the commercial sector, rather than an explicit commitment to its commercial development.

Neither of these characteristics is specific to war: peacetime public, use-oriented R&D programs in unproven technologies, like the previously-discussed DARPA examples or development projects at federally-funded R&D centers, also combine pull and push forces for mission-driven technology development, and can spill over to the commercial sector. Insofar as this is the case, we believe the paper offers useful insights for these contexts. As Mowery (2012) observes, this is characteristic of defense R&D today, which—despite a long history of commercial impact—has never seen civilian technological spillovers as a central goal of these investments.

6.2 Boundary conditions and open questions

There are nevertheless potentially important ways in which a war—and more broadly, a crisis—is distinctive (e.g., Gross and Sampat 2021). Large, emergent, and rapidly escalating problems can motivate a flood of public R&D funding, and also a greater willingness to take risks on high-potential but unproven solutions—like radar, atomic weapons, or mRNA vaccines. It can motivate the participation of top research talent. Users may likewise have little to lose from an experimental technology, with no real alternatives, smoothing the path to adoption. All three were true in World War II. Thus, although—or perhaps because—its principal aim was to help win a war, the radar program bridged a "valley of death" for commercial development at the same time as it developed a militarily important new technology, sinking large R&D investments against uncertainty, and incubating the industry to the doorstep of commercialization.

Our main result is thus demonstrative: a coordinated, use-oriented R&D program can cultivate commercial industries around radical new technologies. This does not mean it always will. Given that this example was borne out of a crisis, and that others are often also driven by urgent needs, a basic question is whether "mission" approaches have similar impacts in other contexts—especially when the need is less urgent, harder to articulate, diffuse across many users, or requires more than technological innovation to resolve. This question is more widely contended in academic literature, with advocates of mission approaches to R&D and industrial policy (e.g., Mazzucato 2018, 2021) and cautionary voices (Mowery et al. 2010). In our view, it is difficult to make claims of generality without more data points or a strong theory of how these contextual features affect outcomes (e.g., Gross and Sampat 2022c). As is, the more closely modern problems parallel historical cases and prior models, the more informative we believe they would be.

A number of other questions remain. One question is to what extent coordinated, multi-firm R&D programs raise barriers to entry, entrenching industry participants. These barriers may conceivably include formal intellectual property, tacit know-how, access to critical human or physical capital, locked-in customer relationships, and more. A second, related question is which firms choose to engage in government-led R&D programs, and why? A third opportunity is to study the evolution of more mature industries through a crisis, including potentially accelerated obsolescence. Further research on these questions will enrich scholarly understanding in an area that, in the aftermath of the COVID pandemic, we believe is ripe for further attention.

References

Abernathy, William J, James M Utterback et al. 1978. "Patterns of industrial innovation," *Technology Review*, Vol. 80, No. 7, pp. 40–47.

Agarwal, Rajshree and Barry L Bayus. 2002. "The market evolution and sales takeoff of product innovations," *Management Science*, Vol. 48, No. 8, pp. 1024–1041.

Agarwal, Rajshree and Michael Gort. 1996. "The evolution of markets and entry, exit and survival of firms," *The Review of Economics and Statistics*, Vol. 78, No. 3, pp. 489–498.

Agarwal, Rajshree, Seojin Kim, and Mahka Moeen. 2021. "Leveraging private enterprise: Incubation of new industries to address the public sector's mission-oriented grand challenges," *Strategy Science*, Vol. 6, No. 4, pp. 385–411.

Agarwal, Rajshree, Mahka Moeen, and Sonali K Shah. 2017. "Athena's birth: Triggers, actors, and actions preceding industry inception," *Strategic Entrepreneurship Journal*, Vol. 11, No. 3, pp. 287–305.

Agarwal, Rajshree and Mary Tripsas. 2008. "Technology and industry evolution," in Shane, Scott ed. *The Handbook of Technology and Innovation Management*, West Sussex: John Wiley & Sons, pp. 1–55.

Alic, John A, Lewis M Branscomb, Harvey Brooks, and Ashton B Carter. 1992. *Beyond spinoff: Military and commercial technologies in a changing world*. Boston: Harvard Business Press.

Argyres, Nicholas S, Alfredo De Massis, Nicolai J Foss, Federico Frattini, Geoffrey Jones, and Brian S Silverman. 2020. "History-informed strategy research: The promise of history and historical research methods in advancing strategy scholarship," *Strategic Management Journal*, Vol. 41, No. 3, pp. 343–368.

Argyres, Nicholas S and Brian S Silverman. 2004. "R&D, organization structure, and the development of corporate technological knowledge," *Strategic Management Journal*, Vol. 25, No. 8-9, pp. 929–958.

Arrow, Kenneth. 1962. "Economic welfare and the allocation of resources for invention," in *The Rate and Direction of Inventive Activity: Economic and Social Factors*, Princeton: Princeton University Press, pp. 609–626.

Aversa, P, S Furnari, and M Jenkins. 2020. "The primordial soup of cluster genesis: An historical case of the British Motor Valley," *Working paper*, pp. 1–60.

Aversa, Paolo, Emanuele Bianchi, Loris Gaio, and Alberto Nucciarelli. 2021. "The grand tour: The role of catalyzing places for industry emergence," *Academy of Management Journal*, Vol. ja.

Azoulay, Pierre, Erica Fuchs, Anna P Goldstein, and Michael Kearney. 2019. "Funding breakthrough research: Promises and challenges of the 'ARPA Model'," *Innovation Policy and the Economy*, Vol. 19, No. 1, pp. 69–96.

Baldwin, Carliss, Christoph Hienerth, and Eric Von Hippel. 2006. "How user innovations become commercial products: A theoretical investigation and case study," *Research Policy*, Vol. 35, No. 9, pp. 1291–1313.

Baxter, James Phinney. 1946. *Scientists against time*. Boston: Little, Brown and Company.

Berkes, Enrico. 2018. *Comprehensive Universe of U.S. Patents (CUSP): Data and Facts*. Working paper.

Bonvillian, William B. 2018. "DARPA and its ARPA-E and IARPA clones: A unique innovation organization model," *Industrial and Corporate Change*, Vol. 27, No. 5, pp. 897–914.

Braguinsky, Serguey and David A Hounshell. 2016. "History and nanoeconomics in strategy and industry evolution research: Lessons from the Meiji-Era Japanese cotton spinning industry," *Strategic Management Journal*, Vol. 37, No. 1, pp. 45–65.

Bryant, John. 1991. "Lee L. Davenport, an oral history conducted in 1991 by John Bryant, IEEE History Center," https://ethw.org/Oral-History:Lee_Davenport (last accessed 7 July 2022).

Buderi, Robert. 1996. *The invention that changed the world: The story of radar from war to peace*. New York: Little, Brown, and Company.

Cattani, Gino. 2006. "Technological pre-adaptation, speciation, and emergence of new technologies: How Corning invented and developed fiber optics," *Industrial and Corporate Change*, Vol. 15, No. 2, pp. 285–318.

Dietz, James S and Barry Bozeman. 2005. "Academic careers, patents, and productivity: industry experience as scientific and technical human capital," *Research Policy*, Vol. 34, No. 3, pp. 349–367.

Dobbin, Frank and Timothy J Dowd. 1997. "How policy shapes competition: Early railroad foundings in Massachusetts," *Administrative Science Quarterly*, pp. 501–529.

Eklund, John C. 2022. "The knowledge-incentive tradeoff: Understanding the relationship between research and development decentralization and innovation," *Strategic Management Journal*, Vol. 43, No. 12, pp. 2478–2509.

Fleming, Lee, Hillary Greene, G Li, Matt Marx, and Dennis Yao. 2019. "Government-funded research increasingly fuels innovation," *Science*, Vol. 364, No. 6446, pp. 1139–1141.

Foray, Dominique, David C Mowery, and Richard R Nelson. 2012. "Public R&D and social challenges: What lessons from mission R&D programs?" *Research Policy*, Vol. 41, No. 10, pp. 1697–1702.

Gao, Cheng and Rory McDonald. 2022. "Shaping nascent industries: Innovation strategy and regulatory uncertainty in personal genomics," *Administrative Science Quarterly*, Vol. 67, No. 4, pp. 915–967.

George, Gerard, Jennifer Howard-Grenville, Aparna Joshi, and Laszlo Tihanyi. 2016. "Understanding and tackling societal grand challenges through management research," *Academy of Management Journal*, Vol. 59, No. 6, pp. 1880–1895.

Golder, Peter N, Rachel Shacham, and Debanjan Mitra. 2009. "Innovations' origins: When, by whom, and how are radical innovations developed?" *Marketing Science*, Vol. 28, No. 1, pp. 166–179.

Goldstein, Andrew. 1991a. "Britton Chance: An Interview Conducted by Andrew Goldstein, IEEE History Center, 12 June 1991," https://ethw.org/Oral-History:Britton_Chance (last accessed 7 July 2022).

——— . 1991b. "Royal P. Alliare, Electrical Engineer, an oral history conducted in 1991 by Andrew Goldstein, IEEE History Center," https://ethw.org/Oral-History:Royal_P._Allaire (last accessed 7 July 2022).

Gort, Michael and Steven Klepper. 1982. "Time paths in the diffusion of product innovations," *The Economic*

Journal, Vol. 92, No. 367, pp. 630–653.
Granqvist, Nina, Stine Grodal, and Jennifer L Woolley. 2013. "Hedging your bets: Explaining executives' market labeling strategies in nanotechnology," *Organization Science*, Vol. 24, No. 2, pp. 395–413.
Grigoriou, Konstantinos and Frank T Rothaermel. 2017. "Organizing for knowledge generation: Internal knowledge networks and the contingent effect of external knowledge sourcing," *Strategic Management Journal*, Vol. 38, No. 2, pp. 395–414.
Gross, Daniel P and Bhaven N Sampat. 2021. "The economics of crisis innovation policy: A historical perspective," *AEA Papers & Proceedings*, Vol. 111, pp. 346–450.
——— . 2022a. *America, jump-started: World War II R&D and the takeoff of the U.S. innovation system*. NBER Working Paper No. 27375.
Gross, Daniel P. and Bhaven N Sampat. 2022b. "Crisis innovation policy from World War II to COVID-19," *NBER Entrepreneurship and Innovation Policy and the Economy*, Vol. 1.
Gross, Daniel P and Bhaven N Sampat. 2022c. *The World War II crisis innovation model: What was it, and where does it apply?*. NBER Working Paper No. 27909.
Guerlac, Henry E. 1987. *Radar in World War II*. College Park: American Institute of Physics.
Hall, Bronwyn H, Adam B Jaffe, and Manuel Trajtenberg. 2001. *The NBER patent citation data file: Lessons, insights and methodological tools*. NBER Working Paper No. 8498.
Harvard University. 1946. *Administrative history of the Radio Research Laboratory*.
Jacobides, Michael G. 2005. "Industry change through vertical disintegration: How and why markets emerged in mortgage banking," *Academy of Management Journal*, Vol. 48, No. 3, pp. 465–498.
Kattel, Rainer and Mariana Mazzucato. 2018. "Mission-oriented innovation policy and dynamic capabilities in the public sector."
Katz, J Sylvan and Ben R Martin. 1997. "What is research collaboration?" *Research Policy*, Vol. 26, No. 1, pp. 1–18.
Kevles, Daniel J. 1977. *The physicists: The history of a scientific community in modern America*. New York: Alfred A. Knopf.
Klepper, Steven and Elizabeth Graddy. 1990. "The evolution of new industries and the determinants of market structure," *The RAND Journal of Economics*, Vol. 21, No. 1, pp. 27–44.
Lerner, Josh and Ramana Nanda. 2020. "Venture capital's role in financing innovation: What we know and how much we still need to learn," *Journal of Economic Perspectives*, Vol. 34, No. 3, pp. 237–61.
Li, Guan-Cheng, Ronald Lai, Alexander D'Amour, David M Doolin, Ye Sun, Vetle I Torvik, Z Yu Amy, and Lee Fleming. 2014. "Disambiguation and co-authorship networks of the US patent inventor database (1975-2010)," *Research Policy*, Vol. 43, No. 6, pp. 941–955.
Li, Zhimin and Dmitri Koustas. 2019. "The long-run effects of government spending on structural change: Evidence from Second World War defense contracts," *Economics Letters*, Vol. 178, pp. 66–69.
Marco, Alan C, Michael Carley, Steven Jackson, and Amanda Myers. 2015. *The USPTO Historical Patent Data Files: Two Centuries of Innovation*. Available at https://ssrn.com/abstract=2616724.
Massachusetts Institute of Technology. 1946. *Five years at the Radiation Laboratory*.
Mazzucato, Mariana. 2018. "Mission-oriented innovation policies: Challenges and opportunities," *Industrial and Corporate Change*, Vol. 27, No. 5, pp. 803–815.
——— . 2021. *Mission economy: A moonshot guide to changing capitalism*. New York: Harper Business.
McMillan, G Steven, Francis Narin, and David L Deeds. 2000. "An analysis of the critical role of public science in innovation: the case of biotechnology," *Research Policy*, Vol. 29, No. 1, pp. 1–8.
Mody, Cyrus C M. 2006. "Corporations, universities, and instrumental communities: Commercializing probe microscopy, 1981-1996," *Technology and Culture*, Vol. 47, No. 1, pp. 56–80.
Moeen, Mahka. 2017. "Entry into nascent industries: Disentangling a firm's capability portfolio at the time of investment versus market entry," *Strategic Management Journal*, Vol. 38, No. 10, pp. 1986–2004.
Moeen, Mahka and Rajshree Agarwal. 2017. "Incubation of an industry: Heterogeneous knowledge bases and modes of value capture," *Strategic Management Journal*, Vol. 38, No. 3, pp. 566–587.
Moeen, Mahka, Rajshree Agarwal, and Sonali K Shah. 2020. "Building industries by building knowledge: Uncertainty reduction over industry milestones," *Strategy Science*, Vol. 5, No. 3, pp. 218–244.
Moeen, Mahka and Will Mitchell. 2020. "How do pre-entrants to the industry incubation stage choose between alliances and acquisitions for technical capabilities and specialized complementary assets?" *Strategic Management Journal*, Vol. 41, No. 8, pp. 1450–1489.

Mowery, David C. 2012. "Defense-related R&D as a model for 'Grand Challenges' technology policies," *Research Policy*, Vol. 41, No. 10, pp. 1703–1715.

Mowery, David C, Richard R Nelson, and Ben R Martin. 2010. "Technology policy and global warming: Why new policy models are needed (or why putting new wine in old bottles won't work)," *Research Policy*, Vol. 39, No. 8, pp. 1011–1023.

Nebeker, Frederic. 1991. "Ivan A. Getting, an oral history conducted in 1991 by Frederic Nebeker, IEEE History Center," https://ethw.org/Oral-History:Ivan_A._Getting_(1991) (last accessed 7 July 2022).

Nelson, Richard R. 1959. "The Simple Economics of Basic Scientific Research," *Journal of Political Economy*, Vol. 67, No. 3, pp. 297–306.

——— . 1982. *Government and technical progress: A cross-industry analysis*. New York: Pergamon Press.

Piezunka, Henning and Linus Dahlander. 2014. "Distant Search, Narrow Attention: How Crowding Alters Organizations' Filtering of User Suggestions," in *Academy of Management Proceedings*, p. 12513.

Pillai, Sandeep D, Brent Goldfarb, and David A Kirsch. 2020. "The origins of firm strategy: Learning by economic experimentation and strategic pivots in the early automobile industry," *Strategic Management Journal*, Vol. 41, No. 3, pp. 369–399.

Porter, Michael E. 1980. *Competitive strategy*. New York: Free Press.

Roche, Maria P. 2023. "Academic Entrepreneurship: Entrepreneurial Advisors and Their Advisees' Outcomes," *Organization Science*, Vol. 34, No. 2, pp. 959–986.

Roche, Maria P, Alexander Oettl, and Christian Catalini. 2022. *(Co-) Working in Close Proximity: Knowledge Spillovers and Social Interactions*. NBER Working Paper No. 30120.

Rothaermel, Frank T and Marie Thursby. 2007. "The nanotech versus the biotech revolution: Sources of productivity in incumbent firm research," *Research Policy*, Vol. 36, No. 6, pp. 832–849.

Saad, Theodore A. 1990. "The story of the MIT Radiation Laboratory," *IEEE Aerospace and Electronic Systems Magazine*, Vol. 5, No. 10, pp. 46–51.

Sanderson, Susan Walsh and Kenneth L Simons. 2014. "Light emitting diodes and the lighting revolution: The emergence of a solid-state lighting industry," *Research Policy*, Vol. 43, No. 10, pp. 1730–1746.

Shah, Sonali K and Mary Tripsas. 2007. "The accidental entrepreneur: The emergent and collective process of user entrepreneurship," *Strategic Entrepreneurship Journal*, Vol. 1, No. 1-2, pp. 123–140.

Sine, Wesley D, Heather A Haveman, and Pamela S Tolbert. 2005. "Risky business? Entrepreneurship in the new independent-power sector," *Administrative Science Quarterly*, Vol. 50, No. 2, pp. 200–232.

Skolnik, Merrill I. 2022. "Britannica: History of radar," https://www.britannica.com/technology/radar/History-of-radar (last accessed 7 July 2022).

Stewart, Irvin. 1948. *Organizing scientific research for war: The administrative history of the Office of Scientific Research and Development*. Boston: Little, Brown, and Company.

Suh, Jungkyu. 2022. *Science, Startups and Novelty*. Working paper.

Tripsas, Mary. 1997. "Unraveling the process of creative destruction: Complementary assets and incumbent survival in the typesetter industry," *Strategic Management Journal*, Vol. 18, No. S1, pp. 119–142.

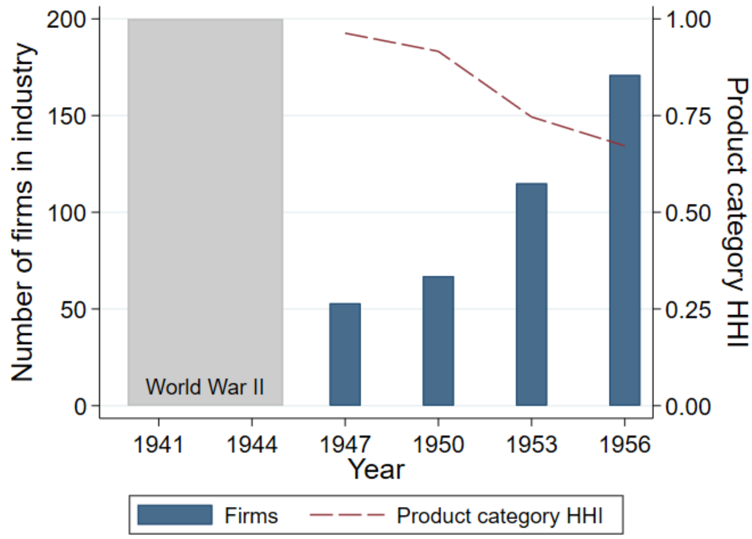
——— . 2008. "Customer preference discontinuities: A trigger for radical technological change," *Managerial and Decision Economics*, Vol. 29, No. 2-3, pp. 79–97.

Zachary, G Pascal. 1997. *Endless frontier: Vannevar Bush, engineer of the American century*. New York: The Free Press.

Zilberman, David, Thomas Reardon, Jed Silver, Liang Lu, and Amir Heiman. 2022. "From the laboratory to the consumer: Innovation, supply chain, and adoption with applications to natural resources," *Proceedings of the National Academy of Sciences*, Vol. 119, No. 23, p. e2115880119.

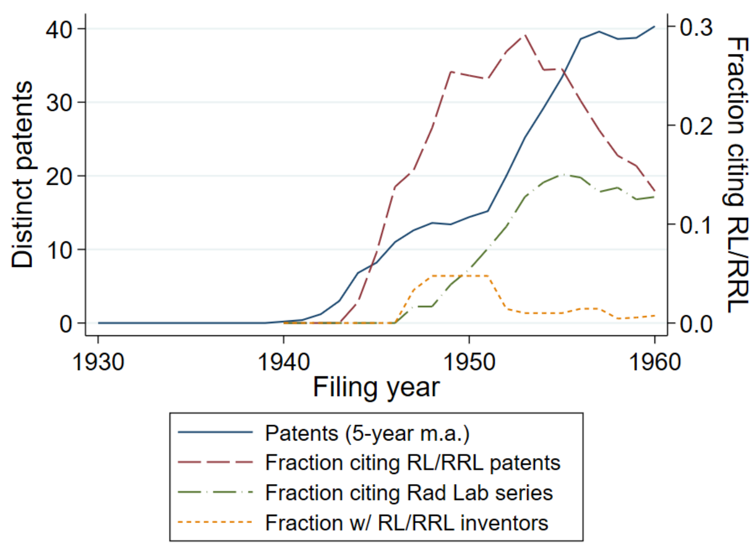
Zucker, Lynne G, Michael R Darby, and Marilynn B Brewer. 1998. "Intellectual human capital and the birth of US biotechnology enterprises," *The American Economic Review*, Vol. 88, No. 1, pp. 290–306.

Figure 1: Radar manufacturing firms in the Thomas Register, 1940s-1950s



Notes: Figure shows count of radar manufacturing firms in successive editions of the Thomas Register of American Manufacturers. The first edition to include radar as a product category was 1944, though firm listings were suppressed for security reasons until 1947. The blue bars count the number of distinct firms in each edition. The red dotted line calculates the concentration of firms across eight radar product categories included in the Thomas Register (e.g., general radar, radar antennae assemblies, radar test equipment, etc.).

Figure 2: RL/RRL-produced resources and firm patenting in radar technology, 1930-1960



Notes: Figure plots the five-year rolling average of annual firm radar patents (left axis), and the share of those patents which (i) cite Rad Lab/RRL patents, (ii) cite the Rad Lab series, and (iii) include Rad Lab/RRL alumni inventors (right axis).

Figure 3: Coordinated R&D programs and the building blocks of new industries

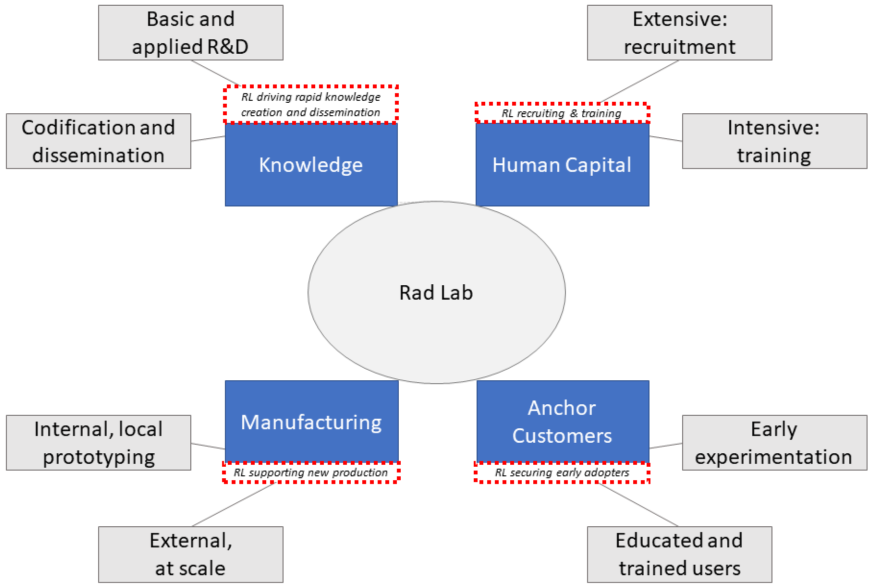


Table 1: Top 10 manufacturers of radar in World War II

Firm	WW2 value (2022 $, BBs)	Pct. of WW2 total	Pct. RL-designed	Defense sector rank WW2	Defense sector rank 1960s	Listed in TRAM? 1947	1950	1953	1956
Western Electric Co.	20.281	39.9%	42.2%	1	53				
General Electric Co.	6.247	12.3%	55.3%	2	4	Y	Y	Y	
Philco Corp.	4.283	8.4%	46.2%	3	34	Y	Y	Y	Y
Raytheon Mfg. Co.	3.741	7.4%	94.1%	4	5	Y	Y	Y	Y
Westinghouse Electric Corp.	3.657	7.2%	56.9%	5	1	Y	Y	Y	Y
Radio Corp. of America	2.150	4.2%	14.2%	6	10				Y
Hazeltine Corp.	1.913	3.8%	0.0%	7	13				
Stewart-Warner Corp.	1.050	2.1%	0.0%	8	26				
Belmont Radio Corp.	1.033	2.0%	1.6%	9	n.a.	n.a.	n.a.	n.a.	n.a.
Sperry Gyroscope Co.	0.863	1.7%	80.4%	10	3	Y	Y	Y	Y

Notes: This table lists the top 10 World War II radar suppliers (by value), based on Guerlac (1987), with values inflated from 1940s levels using a composite wartime adjustment, weighting annual inflation factors by each year's share of radar deliveries. It then ranks them as Department of Defense radar suppliers in 1966-1975, and indicates whether each firm was listed in postwar editions of the Thomas Register of American Manufacturers (TRAM). Belmont Radio Corp. was acquired by Raytheon in 1945 and is not separately listed thereafter.

Table 2: Early postwar industry composition, 1947-1956

		1947	1950	1953	1956
Size and history	Number of firms	53	67	115	171
	Fraction large (>$500K assets)	32%	28%	25%	37%
	Fraction medium (>$100K assets)	42%	36%	38%	35%
	Fraction small (<$100K assets)	26%	36%	34%	27%
	Fraction incumbents (pre-war)	51%	46%	31%	24%
	Fraction WW2 suppliers	19%	15%	9%	6%
Location	Fraction in/around NYC	45%	51%	52%	45%
	Fraction in/around Chicago	4%	3%	5%	5%
	Fraction in/around Boston	6%	4%	5%	7%
R&D	Fraction with R&D labs	53%	55%	53%	48%
	Fraction with patents by 1960	15%	10%	8%	9%

Notes: Table provides characteristics of firms in each year of the Thomas Register (TRAM). Firm size distribution based on TRAM estimates of firm capitalization. Incumbency status measured as an indicator for whether the firm was listed in the 1941 or 1944 editions of TRAM (necessarily in non-radar industries). A complete list of World War II radar equipment suppliers identified through data from Li and Koustas (2019). Research operations measured by searching for TRAM radar firms in the 1946, 1950, or 1956 editions of the National Research Council's directory of Industrial Research Laboratories of the United States. Firm patents measured by manually crosswalking TRAM radar firms to assignees on radar-related U.S. patents.

Table 3: Top 10 patent classes with Rad Lab/RRL patents

USPC	Description	Pct. of patents from RL/RRL, 1943-1946	Govt. funded share of patents	RL/RRL rank among assignees
343	Radio wave antennas	15.5%	59.2%	1
342	Directive radio wave systems/devices (radar)	10.8%	58.2%	2
333	Wave transmission lines and networks	10.4%	51.4%	2
327	Electrical devices, circuits, and systems	7.9%	58.9%	2
315	Electric lamp and discharge device systems	5.5%	28.9%	3
708	Electrical computers: processing	5.4%	39.1%	4
331	Oscillators	4.6%	39.8%	3
455	Telecommunications	4.0%	31.7%	5
332	Modulators	3.9%	22.7%	6
341	Coded data generation	3.8%	22.8%	7

Notes: This table lists the top 10 patent classes with RL/RRL patents between 1943 and 1946 (when nearly all RL/RRL patents were filed). Columns show (i) the RL/RRL share of patents, (ii) the government-funded share of patents, and (iii) the RL/RRL rank against all class assignees.

Table 4: Distinctiveness and impact of Rad Lab/RRL patents

	Std(Maximal similarity)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Text-based	Citation-based	Mult. inventors	Num. citations	≥5 citations	≥10 citations	≥20 citations
1(Is RL/RRL patent)	-0.210***	-0.156***	0.048***	0.754**	0.056***	0.027*	0.011
	(0.037)	(0.038)	(0.018)	(0.301)	(0.022)	(0.016)	(0.009)
N	137861	103256	137660	137862	137862	137862	137862
R^2	0.23	0.09	0.08	0.08	0.06	0.05	0.03
Class-year FEs	Y	Y	Y	Y	Y	Y	Y
Y mean	0.00	0.00	0.17	4.18	0.32	0.10	0.02

Notes: This table estimates differences in assorted characteristics of RL/RRL patents relative to others in the same patent class and filing year. Observations are U.S. patents filed between 1943 and 1946. The outcome variables in Columns (1) and (2) are measures of each patent's maximal similarity to any 1930s patent in the same broader NBER technology category (Hall et al. 2001); when these measures decrease, it indicates the patent was distinctive relative to the pre-1940 stock. The text-based pairwise similarity measure is calculated from word embedding vectors provided in the Google Patents Research dataset (available via Google BigQuery; see Appendix), which are in turn produced from patent text. The citation-based measure is calculated as the proportion of forward citations received by two patents that they share in common, reflecting their proximity in technology space. Both measures are standardized prior to estimation, such that coefficients can be interpreted in units of standard deviations. The outcome in Column (3) is an indicator for whether a patent has multiple inventors; in Column (4), the patent's number of forward citations; in Columns (5) to (7), indicators for whether the patent achieved a given threshold of forward citations. All columns are estimated by OLS and include patent class x filing year fixed effects. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. Robust SEs in parentheses.

Table 5: Changes in research orientation of Rad Lab/RRL inventors: tendency to produce patents in radar classes

	Fraction in Radar USPCs			Any in Radar USPCs		
	(1)	(2)	(3)	(4)	(5)	(6)
	Pre-to-Mid	Mid-to-Post	Pre-to-Post	Pre-to-Mid	Mid-to-Post	Pre-to-Post
1(Is RL/RRL inventor)	0.232***	-0.100***	0.091**	0.597***	-0.278***	0.310***
	(0.038)	(0.036)	(0.035)	(0.061)	(0.078)	(0.062)
N	76006	38866	58582	76006	38866	58582
R^2	0.71	0.71	0.61	0.73	0.71	0.64
Y mean	0.02	0.02	0.02	0.04	0.06	0.04

Notes: This table estimates differences in differences in the tendency of RL/RRL staff to invent in radar, relative to other inventors, as it changed across the pre-, mid-, and post-war periods. In each panel there are two outcomes: Columns (1) to (3) present intensive measures (the fraction of the inventor's patents of a given type), and Columns (4) to (6) intensive measures (any patents of a given type, conditional on patenting at all). The third and sixth columns are our preferred specifications, being indicative of lasting shifts in inventive behavior. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. Robust SEs in parentheses.

Table 6: Quality of patents with Rad Lab/RRL inventors

Panel A: Quality of pre-war patents with Rad Lab/RRL inventors

	(1) Num. citations	(2) Any citations	(3) ≥5 citations	(4) ≥10 citations	(5) ≥20 citations
Any RL/RRL inventors	0.074	0.014	0.010	0.013	-0.001
	(0.166)	(0.017)	(0.018)	(0.011)	(0.004)
N	396687	396687	396687	396687	396687
R^2	0.08	0.06	0.06	0.04	0.03
Class-year FEs	Y	Y	Y	Y	Y
Y mean	3.02	0.75	0.22	0.06	0.01

Panel B: Quality of post-war patents with Rad Lab/RRL inventors

	(1) Num. citations	(2) Any citations	(3) ≥5 citations	(4) ≥10 citations	(5) ≥20 citations
Any RL/RRL inventors	0.676***	0.026***	0.034***	0.031***	0.012***
	(0.155)	(0.008)	(0.011)	(0.008)	(0.004)
N	577633	577633	577633	577633	577633
R^2	0.08	0.04	0.06	0.05	0.03
Class-year FEs	Y	Y	Y	Y	Y
Y mean	3.77	0.82	0.29	0.08	0.01

Notes: This table estimates differences in the forward citations of patents with Rad Lab/ RRL inventors, relative to others in the same patent class and filing year. Panel (A) does so for patents filed between 1930 and 1940; Panel (B), for patents filed in 1946 to 1960. In Column (4), the patent's number of forward citations; in Columns (5) to (7), indicators for whether the patent achieved a given threshold of forward citations. All columns are estimated by OLS and include patent class x filing year fixed effects. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. Robust SEs in parentheses.

Table 7: Likelihood of having a managerial position in 1960 (NRSTP sample)

		By sector			Manager category	
	(1) All	(2) Industry	(3) Academic	(4) Gov't	(5) R&D	(6) Other
1(Is RL/RRL alum)	0.093***	0.152***	0.088***	0.154*	0.075***	0.017
	(0.025)	(0.044)	(0.031)	(0.089)	(0.024)	(0.016)
N	187715	81137	61601	35875	187715	187715
R^2	0.16	0.15	0.05	0.14	0.10	0.07
Y mean	0.26	0.34	0.09	0.35	0.14	0.11
RL/RRL	338	115	187	26	338	338
Controls	Y	Y	Y	Y	Y	Y

Notes: This table estimates differences in the likelihood that a RL/RRL alum reports having managerial responsibilities in 1960, relative to other scientists in the same employment sector, field, degree level, and vintage. The sample comprises scientists included in the National Roster of Scientific and Technical Personnel (NRSTP), an NSF-led effort to enumerate the full population of the U.S. scientific workforce and its characteristics. Roughly 340 RL/RRL alumni were (manually) linked to the 1960 NRSTP sample. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. Robust SEs in parentheses.

Web Appendix

A Historical Appendix

This appendix section provides additional contextual information on the Rad Lab and RRL. Tables A.1 and A.2 describe the Rad Lab's organizational structure, listing its divisions and working groups. Figure A.1 provides a cutaway diagram of the Rad Lab in 1940, and Figure A.2 identifies in an aerial photograph the full extend of its footprint on MIT's campus. Figure A.3 is a photograph from inside the lab. Figure A.4 documents the RRL's total headcount from 1942 to 1945 (no comparable figure was available for the Rad Lab). Figures A.5 and Figure A.6 provide organizational charts for the Rad Lab and RRL, respectively.

Table A.1: List of Rad Lab Divisions

Division	Name	Chief	Known Staff
1	Business Office	T. F. O'Donnell	95
2	Buildings and Maintenance	J. G. Peter	4
3	Personnel and Shops	F. W. Loomis	51
4	Research	I. I. Rabi	73
5	Transmitter Components	J. R. Zacharias	235
6	Receiver Components	L. J. Haworth	158
7	Beacons	L. A. Turner	46
8	Fire Control and Army Ground Forces	I. A. Getting	81
9	Airborne Systems	M. G. White	78
10	Ground and Ship	J. C. Street	95
11	Navigation	J. A. Pierce	24
12	Field Service	J. G. Trump	13
	(other)	n.a.	50

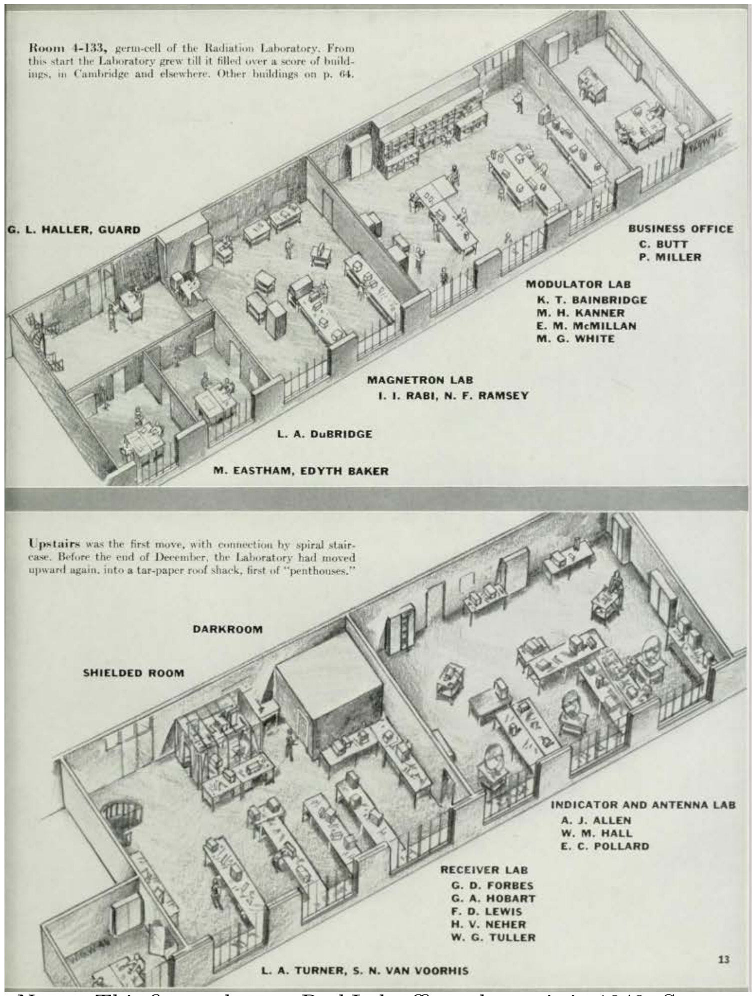
Notes: This table lists Rad Lab divisions, division heads, and staff counts we are able to identify in each. Divisions 4 to 11 were the principal technical divisions. Source: Five Years at the Radiation Laboratory (Massachusetts Institute of Technology 1946).

Table A.2: List of Rad Lab Working Groups

Division	Division name	Group	Group name	Group chief
1	Business Office	11	Statistics	C. W. Buck
1	Business Office	12	Property	W. C. Kendrick
1	Business Office	13	Purchasing	R. H. K. Brown
1	Business Office	14	Priorities	E. M. Crary
1	Business Office	15	Accounting	C. H. Day
1	Business Office	16	Materials Control	W. G. Johnson, Jr.
1	Business Office	17	Stock Rooms	J. E. Bova
1	Business Office	18	Receiving Rooms	S. Y. Mann, Jr.
1	Business Office	19	Shipping Rooms	J. V. Morrison
2	Buildings and Maintenance	22	Maintenance	A. J. Brunini
2	Buildings and Maintenance	26	Painters & Carpenter Shop	R. L. Young
3	Personnel and Shops	31	Personnel	F. W. Loomis
3	Personnel and Shops	32	Drafting	I. W. Lovell
3	Personnel and Shops	33	Transportation	J. H. McNally
3	Personnel and Shops	34	Shop	P. Kohler
3	Personnel and Shops	35	Special Publications and Photography	C. Newton
3	Personnel and Shops	36	Training Program	W. L. Kelly
3	Personnel and Shops	37	Meter Repair	J. F. Nechaj
3	Personnel and Shops	38	Guards	J. A. Beattie
3	Personnel and Shops	39	Manuals & Printing	S. Seely
4	Research	41	Fundamental Development	E. M. Purcel
4	Research	42	Propagation	D. E. Kerr
4	Research	43	Theory	G. E. Uhlenbeck
4	Research	44	Experimental Systems	J. L. Lawson
4	Research	45	Special Dielectrics	O. Halpern
5	Transmitter Components	51	Modulators	H. D. Doolittle
5	Transmitter Components	52	Transmitters	G. B. Collins
5	Transmitter Components	53	Radio Frequency	A. G. Hill
5	Transmitter Components	54	Antennas	L. C. Van Atta
5	Transmitter Components	55	Test Equipment	F. J. Gaffney
5	Transmitter Components	56	Component Engineering	M. M. Hubbard
5	Transmitter Components	57	Special Problems	J. C. Slater
6	Receiver Components	61	Receivers	S. N. Van Voorhis
6	Receiver Components	62	Indicators	C. Sherwin & J. Soller
6	Receiver Components	63	Precision	B. Chance
6	Receiver Components	64	Trainers	R. L. Garman
6	Receiver Components	65	Moving Target Indication	R. A. McConnell
7	Beacons	71	Racons	A. Roberts
7	Beacons	72	Identification	M. D. O'Day
8	Fire Control and Army Ground Forces	81	Systems	L. L. Davenport
8	Fire Control and Army Ground Forces	82	Systems	R. P. Scott
8	Fire Control and Army Ground Forces	83	Servos	N. B. Nichols
8	Fire Control and Army Ground Forces	84	Theory	R. S. Phillips
8	Fire Control and Army Ground Forces	85	Design	J. S. White
9	Airborne Systems	91	(none)	T. W. Bonner
9	Airborne Systems	92	(none)	M. G. White
9	Airborne Systems	93	(none)	W. M. Cady
10	Ground and Ship	101	Mechanical Engineering	M. B. Karelitz
10	Ground and Ship	102	Ship Applications	J. S. Hall & R. E. Meagher
10	Ground and Ship	103	Special Applications	R. M. Emberson
10	Ground and Ship	104	Ground Applications	E. G. Schneider
11	Navigation	111	Laboratory	A. J. Pote
11	Navigation	112	Loran Operational Research	J. A. Pierce
11	Navigation	113	Field Engineering and Procurement	W. L. Tierney

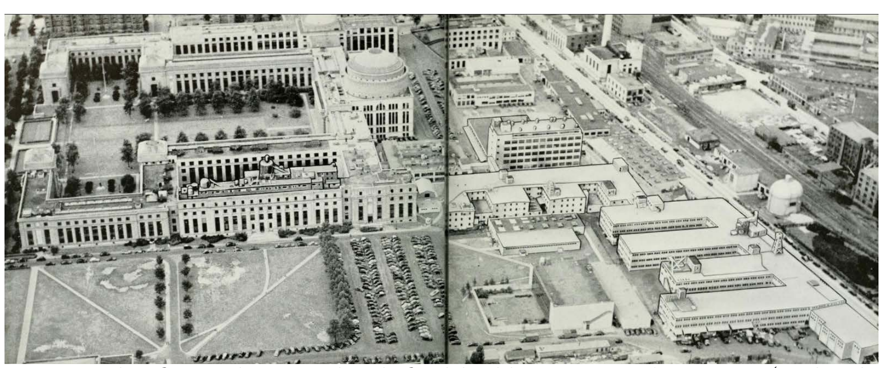
Notes: This table lists Rad Lab working groups. Source: Five Years at the Radiation Laboratory (Massachusetts Institute of Technology 1946).

Figure A.1: Rad Lab Initial Office Schematic, 1940



Notes: This figure shows a Rad Lab office schematic in 1940. Source: Five Years at the Radiation Laboratory (Massachusetts Institute of Technology 1946).

Figure A.2: Rad Lab Buildings at MIT, 1945

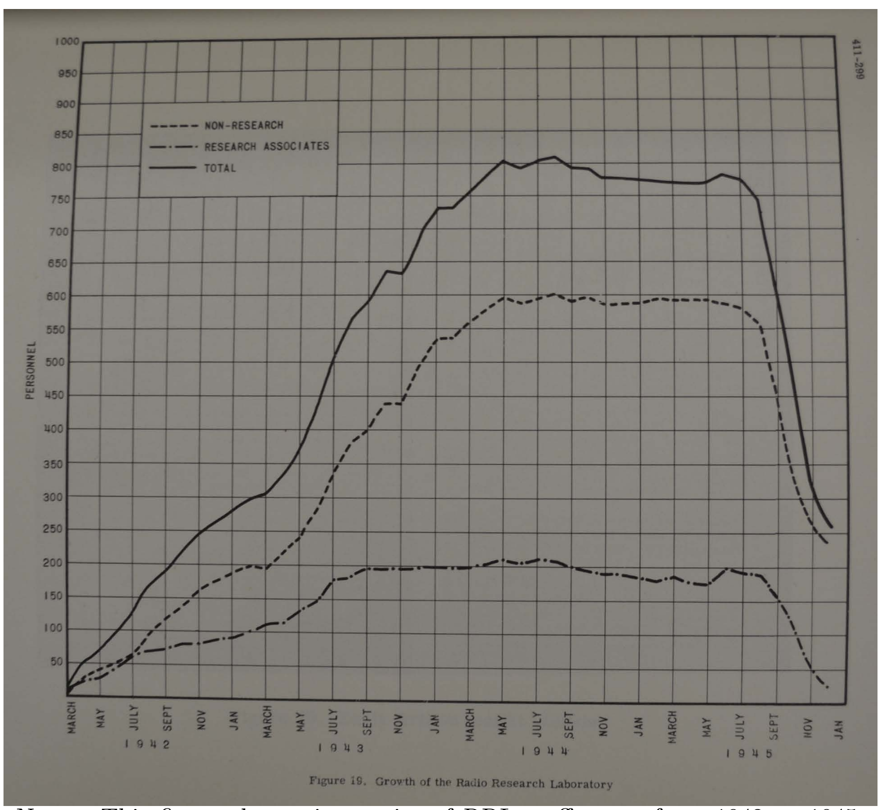


Notes: This figure shows Rad Lab final buildings on MIT's campus (outlined in dark black). Building 20 (the Rad Lab's eventual main building) is at the bottom-right. Source: Five Years at the Radiation Laboratory (Massachusetts Institute of Technology 1946).

Figure A.3: Rad Lab Action Shot, 1940

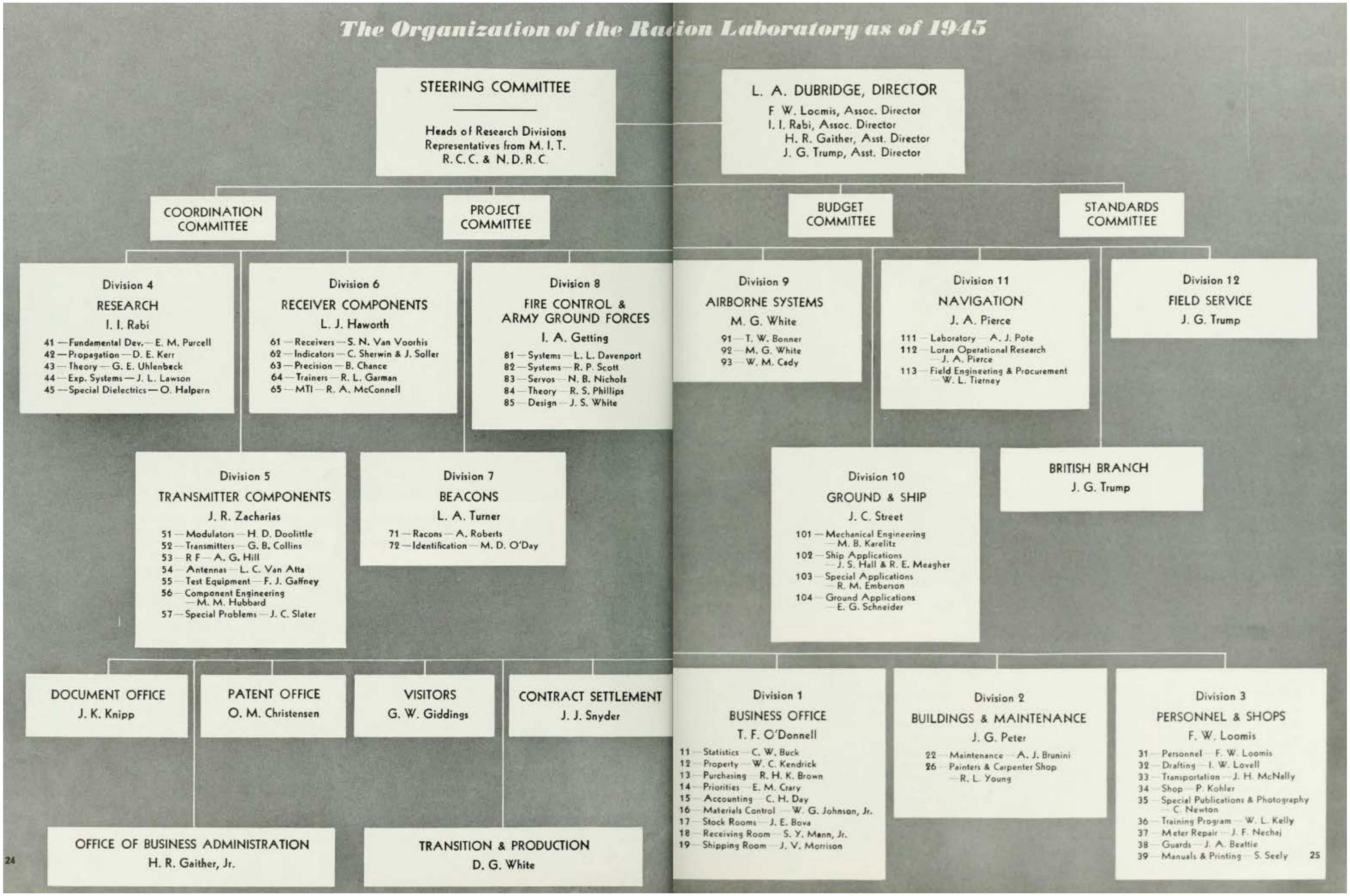
Notes: This figure shows a workroom at the Rad Lab in 1940. Source: Five Years at the Radiation Laboratory (Massachusetts Institute of Technology 1946).

Figure A.4: RRL Staff Count, 1942-1945



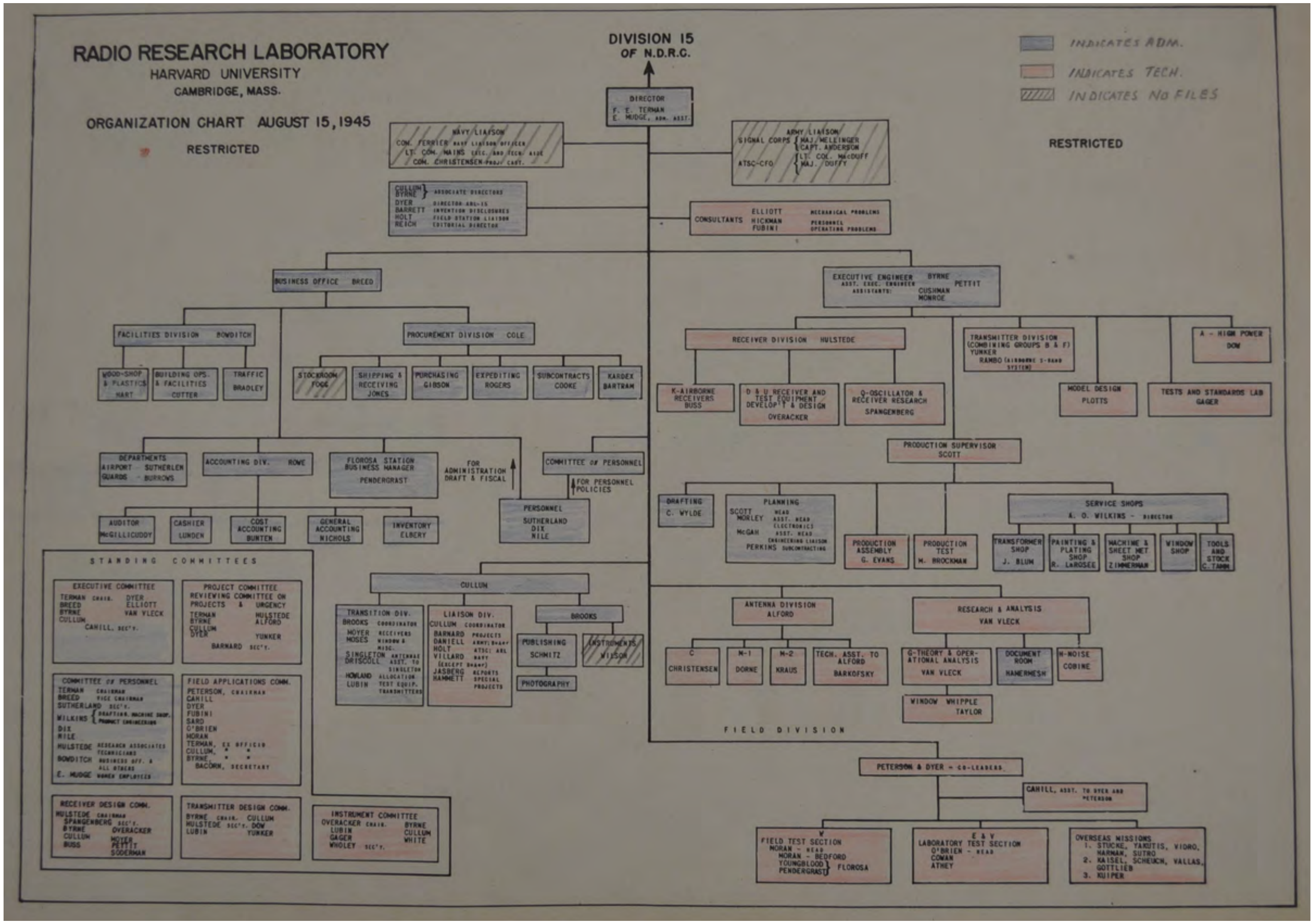
Notes: This figure shows time series of RRL staff count from 1942 to 1945. Source: RRL Administrative History (Harvard University 1946).

Figure A.5: Rad Lab Organization Chart



Notes: This figure provides a Rad Lab organization chart. Source: Five Years at the Radiation Laboratory (Massachusetts Institute of Technology 1946).

Figure A.6: RRL Organization Chart



Notes: This figure provides an RRL organization chart. Source: RRL Administrative History (Harvard University 1946).

B Data Appendix

B.1 Construction of U.S. patent datasets

B.1.1 Base data

The construction of the patent datasets used in this paper begins with the USPTO historical master file (Marco et al. 2015), which provides a master list of utility patents with grant dates, patent class/subclass (USPC), and two-digit NBER category (Hall et al. 2001). In building this paper's dataset, we restrict the sample to patents granted between January 1, 1920 and December 31, 1979—although most of the paper invokes only a subset of these, emphasizing the sample filed between 1930 and 1960. For all granted patents in this set, we obtain additional patent characteristics from the following sources:

- FreePatentsOnline.com (FPO): serial numbers, filing dates, and the network of forward and backward citations (front-page citations only)
- Clarivate Derwent Innovation database (DI): assignee names[1]
- Google Patents: titles, top terms, word embedding vectors

The DI assignee names are (mostly) standardized and were later found to match those in Google Patents data, which are freely available through Google BigQuery. These data are mostly complete, but a small number of patents are missing filing dates and assignees. Table B.1 shows the number patents with missing data, by decade of grant. For the period sampled in this paper (1930-1960), approximately 2.5% of patents are missing a filing date and 2.5% missing an assignee (note: these percentages are calculated for patents granted between 1930 and 1960, whereas the paper uses the sample of patents known to have been filed between 1930 and 1960).

Table B.1: Number of patents with missing data, by decade

		No filing date		No assignee data	
Decade of grant	Patents	Number	Percent	Number	Percent
1920-1929	414901	25738	6.2%	25918	6.2%
1930-1939	442842	11102	2.5%	11221	2.5%
1940-1949	307630	5470	1.8%	5546	1.8%
1950-1959	425985	12461	2.9%	12661	3.0%
1960-1969	567761	11203	2.0%	11363	2.0%
1970-1979	689027	2	0.0%	73	0.0%
Total	2848146	65976	2.3%	66782	2.3%

Notes: Table shows counts of patents with missing data, and their fraction of all patents, by decade.

[1] Note that serial numbers, filing dates, and the network of patent citations were also retrieved from the Derwent database for comparison against the FPO data, as a validation exercise. The two data sources overwhelmingly agreed, and where they disagreed, spot checks revealed that FPO was consistently the more accurate of the two, and when there was an error in the FPO data, it typically reflected the occasional typographical error on the printed patent publication itself, such as two flipped digits, or a digit one unit off the correct value. Given their reliability, the data for this paper thus use serial numbers, filing dates, and citations from FPO.

Patented, OSRD-funded inventions are identified in the OSRD archival records by the serial number of the patent application. It is thus critical to have accurate data on serial numbers. We manually reviewed and validated the application-level data (serials and filing dates) from FPO for the period around World War II by checking patents with serial numbers or filing dates which are out of sequence. The important feature of the USPTO's application numbering system for our purposes here is that applications are organized into application "series", which span several years, and identified by a serial number within that series, generally issued in the order in which patent applications arrive at the USPTO, with serial numbers never exceeding six digits. Application series increment, and serial numbers reset, at the beginning of a year in which the serial numbers from the previous series are expected to surpass 1,000,000. Series 2 begins January 1, 1935 and ends December, 1947 and is the focus of this data cleaning effort. We take all patents identified by FPO as belonging to Series 2 and sort these patents by serial. We then look for patents where the previous and next serial have the same filing date but the given patent has a different filing date, and then manually validate the serial and filing date for these patents. Out of over 370,000 patents in Series 2, corrections were made to 279 serials and 188 filing dates. Although these corrections are valuable for matching patents to serials in OSRD records, the low error rate for this sample also indicates that such errors are not widespread in the data.

B.1.2 Harmonizing assignee names

Although the assignee names from DI are largely already standardized, closer examination reveals that there are still variants on individual assignee names (e.g., BELL TELEPHONE LABOR INC with >10,000 patents, and BELL TELPHONE LAB INC, BELL TEL PHONE LAB INC, and BELL TEIEPHONE LAB INC with 1 patent each). We undertake several procedures to further harmonize assignee names. We begin by sorting a list of assignees in alphabetical order, and for each assignee recording other nearby assignees up to 9 positions before/after in the sorted list. We then calculate the edit distance between the given assignee name and each of these nearby assignee names. When this edit distance is less than 25% of the length of the longer name in each pair, We flag that pair as a candidate for manual review. We then review all such matches for several categories of assignees, and standardize names when a match is found:

- Assignees with ≥15 patents between 1930 and 1960
- Assignees which were OSRD contractors
- Assignees identified as government agencies (see next section)
- Assignees identified as universities or hospitals (see next section)
- Assignees which were synthetic rubber manufacturers
- Assignees which were spinouts from Standard Oil

This process is repeated (because each round of harmonization may bring new assignees into the set with ≥15 patents between 1930 and 1960) until no new matches are found.

This harmonization is neither perfect nor exhaustive, but it is believed to be effective for the purposes of this paper. It is also worth noting that for the vast majority of assignee names which were standardized by this procedure, there was clearly a primary spelling for that assignee in the original DI data, with hundreds or thousands of associated patents in the case of large assignees, and at worst a handful of secondary spellings with one or two associated patents—such that the actual effects of both (i) performing this harmonization for the priority assignees above, and of (ii) not performing it for non-priority assignees, are likely minimal.

B.1.3 Determining assignee types

Assignees are then classified into four categories—firms, universities and hospitals, government agencies, and individuals—through a combination of rule-based and manual classification. We begin by classifying assignees as firms when the assignee name includes any of roughly 120 words which indicate firms (e.g., CO, CORP, INC, LTD, SPA, GMBH, etc., as well as technical words such as AERO, AUTO, CHEM, ENG, MACHINE, OIL, PROD, TECH, WORKS; full list available on request). We then manually classify remaining assignees with ≥ 15 patents between 1930 and 1960, as well as assignees whose name includes any of the following strings:

- COLLEGE, INST, UNIV, HOSP, RES FOUND
- US, CANADA, UK, FRANCE, GERMANY, SWITZERLAND, AUSTRALIA, JAPAN, ISRAEL, and assorted other countries
- ATOM (to identify international atomic energy commissions)

Assignees with >200 patents in the 1920-1979 period which are thus far unclassified are then classified as firms. Any remaining unclassified assignees are classified as individuals.

This procedure was developed over several years, and although—like the name harmonization—it is neither perfect nor exhaustive, random spot checks suggest it is overwhelmingly effective at categorizing assignees into the right bins. In total, 60.1% of patents with an assignee in the 1920-1979 sample are assigned to a firm, 0.2% to a university, 0.8% to a government agency, and 39.1% to an individual (numbers sum to >100% because 5% of patents have multiple assignees, and 0.2% have assignees in multiple categories). Using administrative data, we will see below that the fraction we measure through names as assigned to a government entity is an undercount, primarily because the DI data sometimes undermeasure patent assignment.

B.1.4 Identifying Rad Lab and RRL patents

We use the OSRD archival data collected by Gross and Sampat (2022a) to identify Rad Lab and RRL patents. Archival records include an index of OSRD contracts and of inventions developed under these contracts, which contractors were required to disclose. We are able to identify the individual OSRD contracts under which the Rad Lab and RRL operated, and in turn all associated inventions, patent applications, and granted patents.[2] Out of all 3,134 patents generated by OSRD-funded research that granted by 1980, a total of 588 (i.e., about 20%) were produced by the Rad Lab and RRL (472 and 116 from each lab, respectively).

B.2 Data on Rad Lab and RRL staff

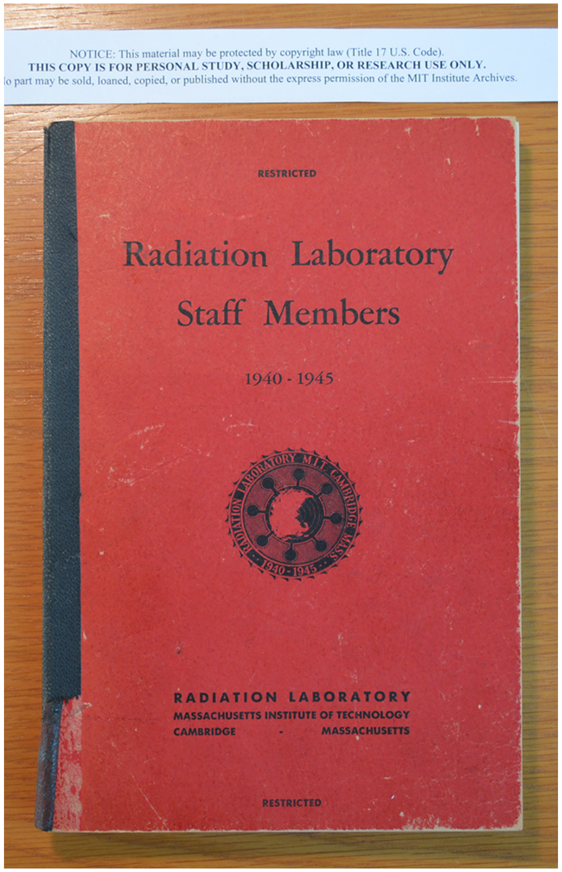
Information on Rad Lab and RRL technical staff was also obtained from their respective archival records. Our starting point was the records of the Rad Lab maintained at MIT. These records include a roster of staff members who worked at the Cambridge laboratory, with a biography accompanying each employee that lists their (i) field, (ii) degree year, level, institution, and subject for all degrees, (iii) work at the Rad Lab, and (iv) postwar place of employment or study. A second book provides postwar placements, organized by company/institution. A third book gives the known address for each staff member. The RRL archival records at Harvard provide similar, albeit less comprehensive, data on its staff, provisioning a list of names and addresses only. Figures B.1 to B.4 show samples from each of these data sources.

We gather more data on the Rad Lab from the publication "Five Years at the Radiation Laboratory" (Massachusetts Institute of Technology 1946), a yearbook that chronicles the organization's history, by year; describes the work of each of its divisions; and lists staff members' associations inside the lab. This publication provides insight into which staff members may have worked closely together at the Rad Lab during the war. No similar publication is available for the RRL, which was also a smaller organization, peaking at one-fifth the Rad Lab's size.

The sets of names in each of these data sources are partly but not fully overlapping. The Rad Lab staff roster, address list, and placement list contain 1362, 1353, and 942 names, respectively. We believe the staff roster covers most of the Rad Lab's technical staff: as Appendix Figure B.1 shows, the individuals in this list are nearly all scientists and engineers, though it should be noted that the precise sampling process is not known. Of the individuals in this roster, we have addresses for 99% and postwar job placement for 68%; 70% could also be found in the yearbook. By comparison, the RRL directory lists 1043 staff members, but it likely includes more non-technical staff, given that we know the RRL was younger and smaller. Thirty-four individuals appear in the staff lists of both labs, reflecting the intrinsic linkages between them.

[2] For completeness, in Gross and Sampat (2022a) we also search for continuations, divisions, and continuations-in-part of OSRD patent applications, extending this set by a handful of patents.

Figure B.1: Rad Lab staff roster, compiled June 1946 (MIT Institute Archives)



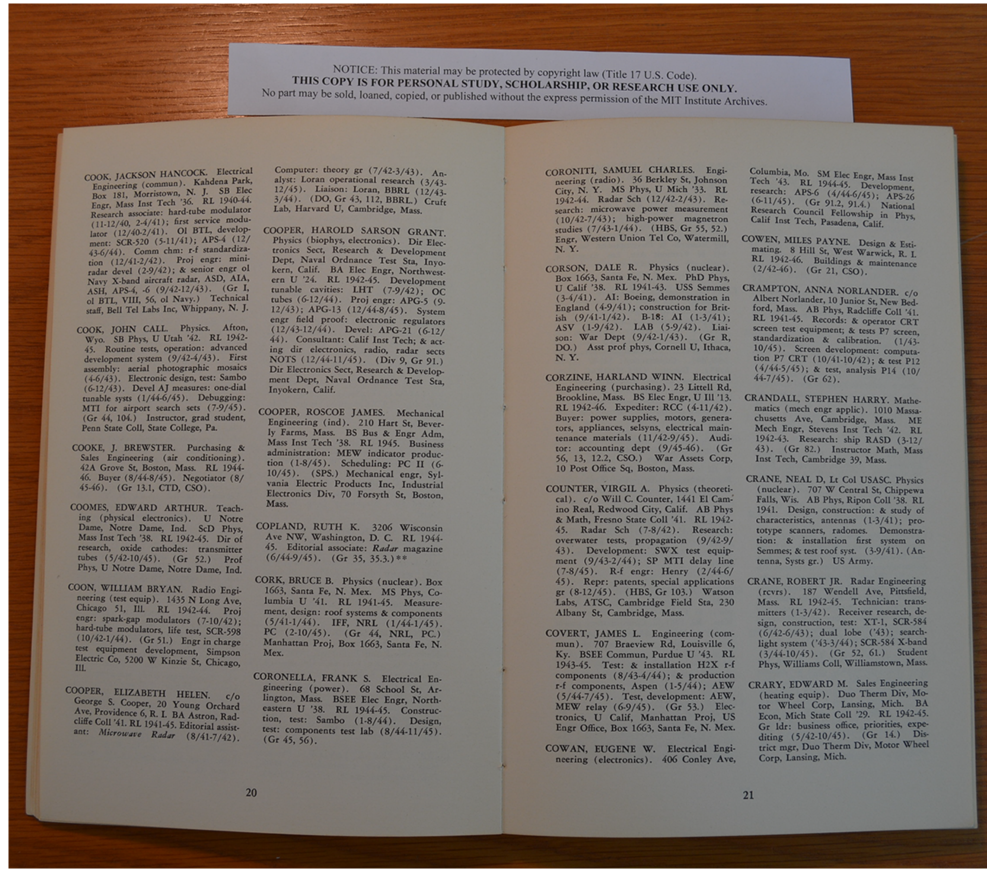
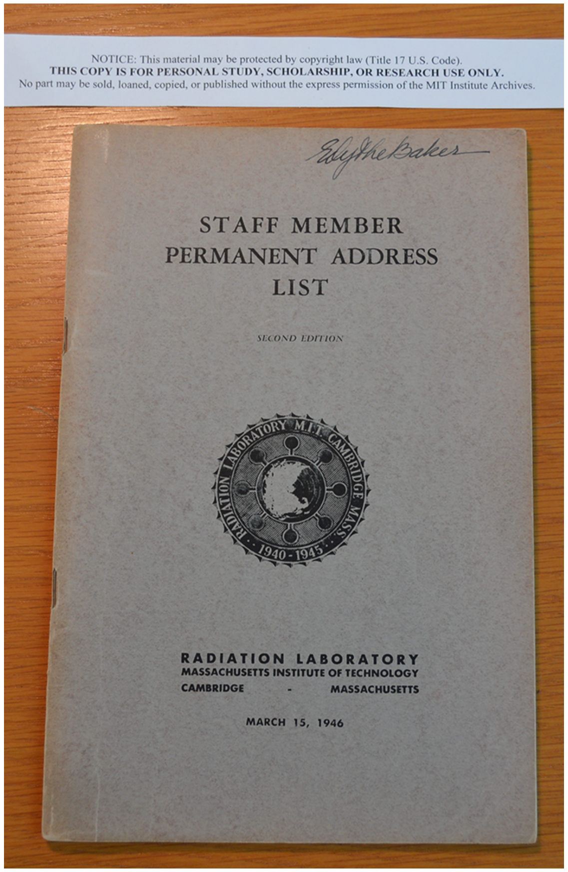
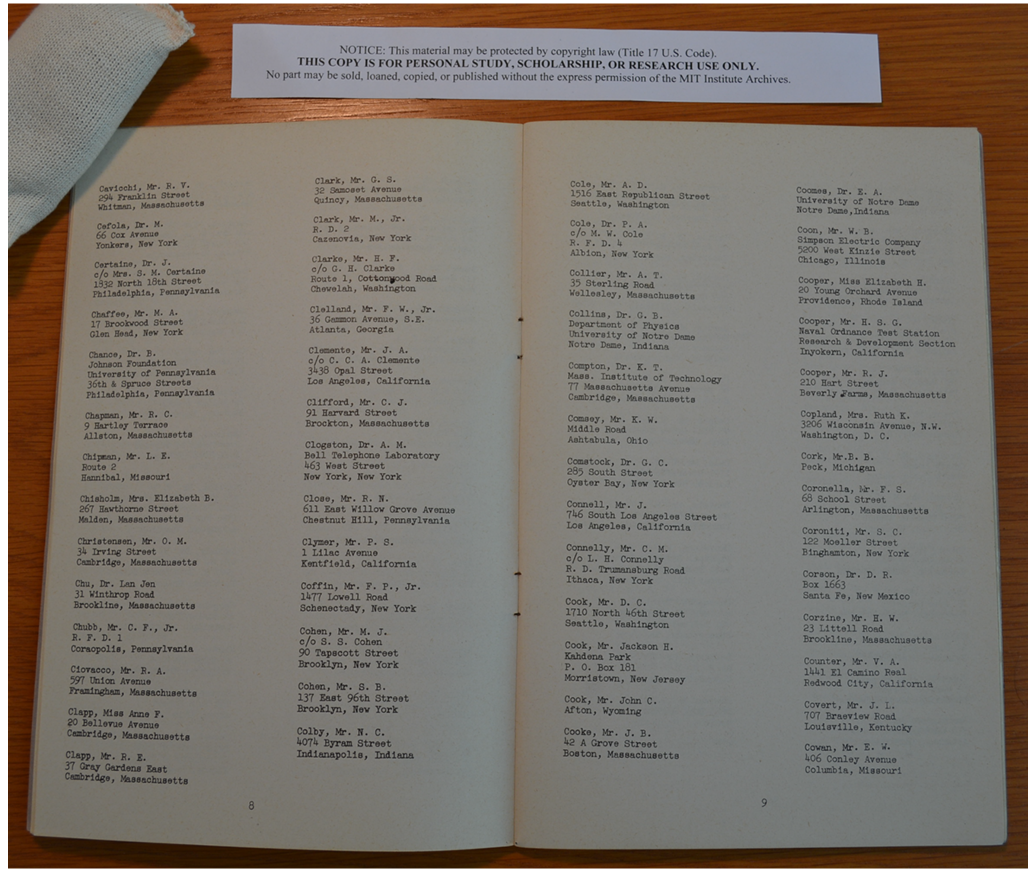


Figure B.2: Rad Lab staff addresses, compiled March 1946 (MIT Institute Archives)





Cavicchi, Mr. R. V.
294 Franklin Street
Whitman, Massachusetts

Cefola, Dr. M.
66 Cox Avenue
Yonkers, New York

Certaine, Dr. J.
c/o Mrs. S. M. Certaine
1832 North 18th Street
Philadelphia, Pennsylvania

Chaffee, Mr. M. A.
17 Brookwood Street
Glen Head, New York

Chance, Dr. B.
Johnson Foundation
University of Pennsylvania
36th & Spruce Streets
Philadelphia, Pennsylvania

Chapman, Mr. R. C.
9 Hartley Terrace
Allston, Massachusetts

Chipman, Mr. L. E.
Route 2
Hannibal, Missouri

Chisholm, Mrs. Elizabeth B.
267 Hawthorne Street
Malden, Massachusetts

Christensen, Mr. O. M.
34 Irving Street
Cambridge, Massachusetts

Chu, Dr. Lan Jen
31 Winthrop Road
Brookline, Massachusetts

Chubb, Mr. C. F., Jr.
R. F. D. 1
Coraopolis, Pennsylvania

Ciovacco, Mr. R. A.
597 Union Avenue
Framingham, Massachusetts

Clapp, Miss Anne F.
20 Bellevue Avenue
Cambridge, Massachusetts

Clapp, Mr. R. E.
37 Gray Gardens East
Cambridge, Massachusetts

Clark, Mr. G. S.
32 Samoset Avenue
Quincy, Massachusetts

Clark, Mr. M., Jr.
R. D. 2
Cazenovia, New York

Clarke, Mr. H. F.
c/o G. H. Clarke
Route 1, Cottonwood Road
Chewelah, Washington

Clelland, Mr. F. W., Jr.
36 Gammon Avenue, S.E.
Atlanta, Georgia

Clemente, Mr. J. A.
c/o C. C. A. Clemente
3438 Opal Street
Los Angeles, California

Clifford, Mr. C. J.
91 Harvard Street
Brockton, Massachusetts

Clogston, Dr. A. M.
Bell Telephone Laboratory
463 West Street
New York, New York

Close, Mr. R. N.
611 East Willow Grove Avenue
Chestnut Hill, Pennsylvania

Clymer, Mr. P. S.
1 Lilac Avenue
Kentfield, California

Coffin, Mr. F. P., Jr.
1477 Lowell Road
Schenectady, New York

Cohen, Mr. M. J.
c/o S. S. Cohen
90 Tapscott Street
Brooklyn, New York

Cohen, Mr. S. B.
137 East 96th Street
Brooklyn, New York

Colby, Mr. N. C.
4074 Byram Street
Indianapolis, Indiana

8

Cole, Mr. A. D.
1516 East Republican Street
Seattle, Washington

Cole, Dr. P. A.
c/o M. W. Cole
R. F. D. 4
Albion, New York

Collier, Mr. A. T.
35 Sterling Road
Wellesley, Massachusetts

Collins, Dr. G. B.
Department of Physics
University of Notre Dame
Notre Dame, Indiana

Compton, Dr. K. T.
Mass. Institute of Technology
77 Massachusetts Avenue
Cambridge, Massachusetts

Comsey, Mr. K. W.
Middle Road
Ashtabula, Ohio

Comstock, Dr. G. C.
285 South Street
Oyster Bay, New York

Connell, Mr. J.
746 South Los Angeles Street
Los Angeles, California

Connelly, Mr. C. M.
c/o L. H. Connelly
R. D. Trumansburg Road
Ithaca, New York

Cook, Mr. D. C.
1710 North 46th Street
Seattle, Washington

Cook, Mr. Jackson H.
Kahdena Park
P. O. Box 181
Morristown, New Jersey

Cook, Mr. John C.
Afton, Wyoming

Cooke, Mr. J. B.
42 A Grove Street
Boston, Massachusetts

Coomes, Dr. E. A.
University of Notre Dame
Notre Dame,Indiana

Coon, Mr. W. B.
Simpson Electric Company
5200 West Kinzie Street
Chicago, Illinois

Cooper, Miss Elizabeth H.
20 Young Orchard Avenue
Providence, Rhode Island

Cooper, Mr. H. S. G.
Naval Ordnance Test Station
Research & Development Section
Inyokern, California

Cooper, Mr. R. J.
210 Hart Street
Beverly Farms, Massachusetts

Copland, Mrs. Ruth K.
3206 Wisconsin Avenue, N.W.
Washington, D. C.

Cork, Mr.B. B.
Peck, Michigan

Coronella, Mr. F. S.
68 School Street
Arlington, Massachusetts

Coroniti, Mr. S. C.
122 Moeller Street
Binghamton, New York

Corson, Dr. D. R.
Box 1663
Santa Fe, New Mexico

Corzine, Mr. H. W.
23 Littell Road
Brookline, Massachusetts

Counter, Mr. V. A.
1441 El Camino Real
Redwood City, California

Covert, Mr. J. L.
707 Braeview Road
Louisville, Kentucky

Cowan, Mr. E. W.
406 Conley Avenue
Columbia, Missouri

9

Figure B.3: Rad Lab staff placement, compiled January 1946 (MIT Institute Archives)

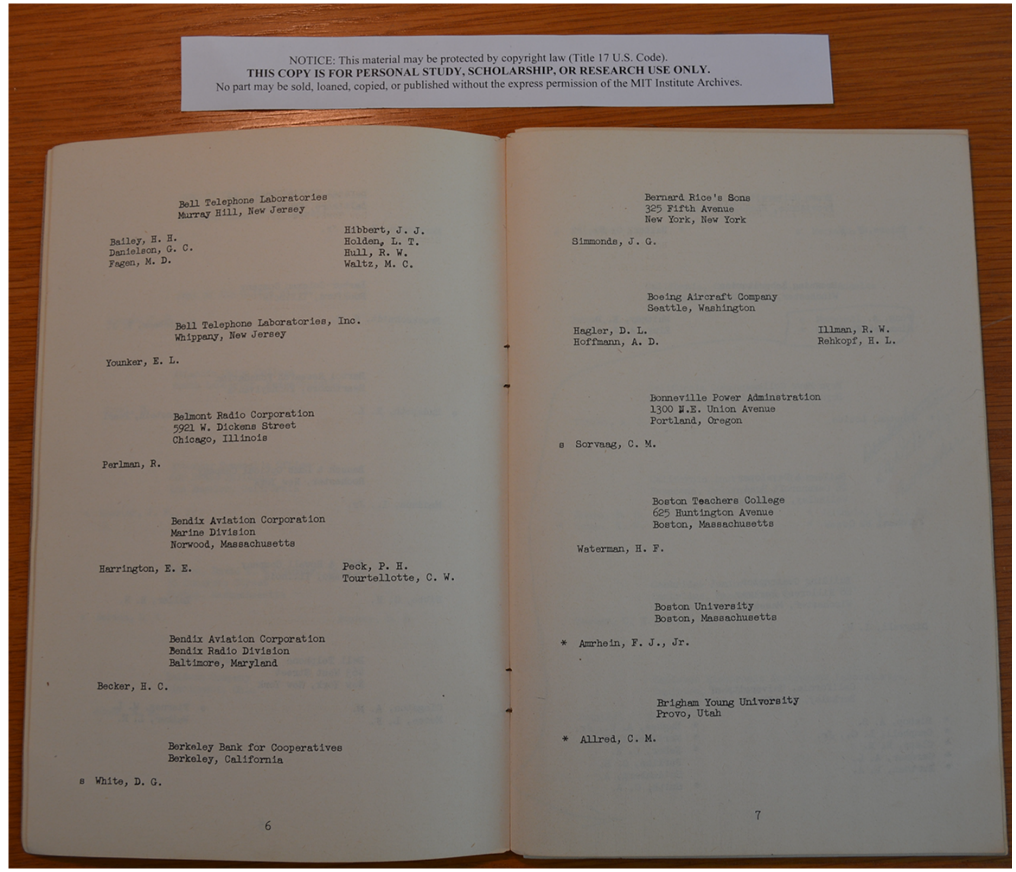
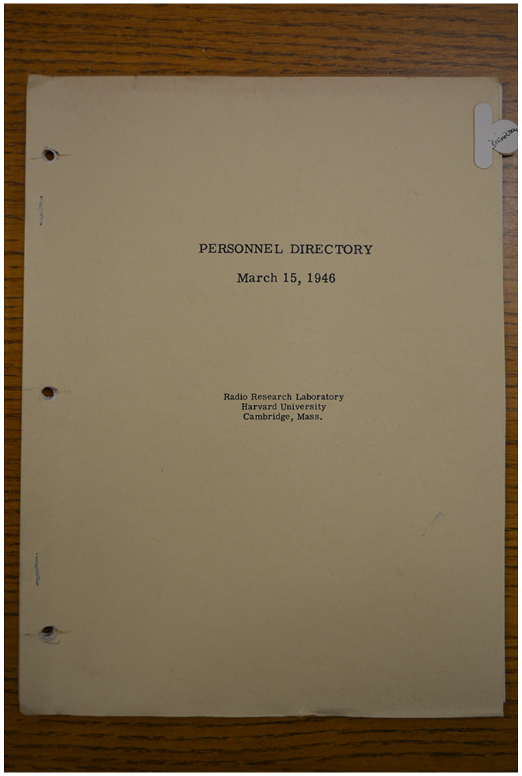


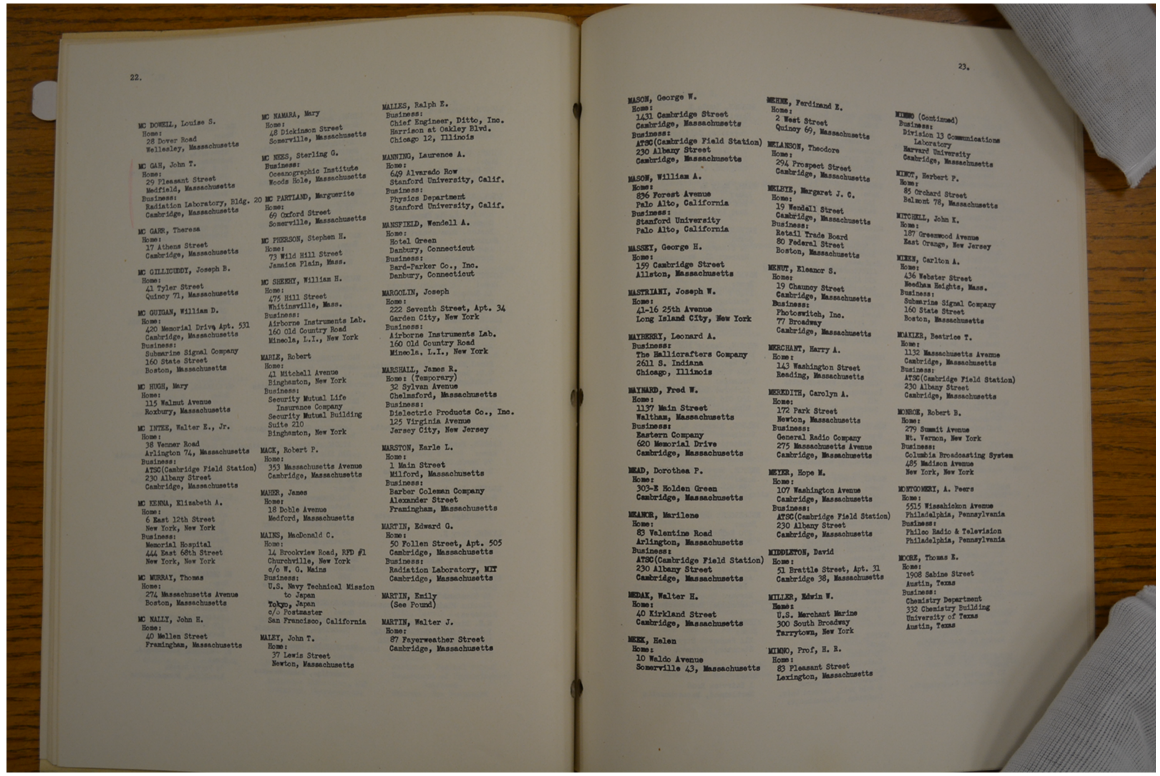
Figure B.4: RRL personnel directory, compiled March 1946 (Harvard University Archives)



PERSONNEL DIRECTORY

March 15, 1946

Radio Research Laboratory
Harvard University
Cambridge, Mass.



22.

MC DOWELL, Louise S.
Home:
28 Dover Road
Wellesley, Massachusetts

MC GAH, John T.
Home:
29 Pleasant Street
Medfield, Massachusetts
Business:
Radiation Laboratory, Bldg. 20
Cambridge, Massachusetts

MC GARR, Theresa
Home:
17 Athens Street
Cambridge, Massachusetts

MC GILLICUDDY, Joseph B.
Home:
41 Tyler Street
Quincy 71, Massachusetts

MC GUIGAN, William D.
Home:
420 Memorial Drive, Apt. 531
Cambridge, Massachusetts
Business:
Submarine Signal Company
160 State Street
Boston, Massachusetts

MC HUGH, Mary
Home:
115 Walnut Avenue
Roxbury, Massachusetts

MC INTEE, Walter E., Jr.
Home:
38 Venner Road
Arlington 74, Massachusetts
Business:
ATSC(Cambridge Field Station)
230 Albany Street
Cambridge, Massachusetts

MC KENNA, Elizabeth A.
Home:
6 East 12th Street
New York, New York
Business:
Memorial Hospital
444 East 68th Street
New York, New York

MC MURRAY, Thomas
Home:
274 Massachusetts Avenue
Boston, Massachusetts

MC NALLY, John H.
Home:
40 Mellen Street
Framingham, Massachusetts

MC NAMARA, Mary
Home:
48 Dickinson Street
Somerville, Massachusetts

MC NEES, Sterling G.
Business:
Oceanographic Institute
Woods Hole, Massachusetts

MC PARTLAND, Marguerite
Home:
69 Oxford Street
Somerville, Massachusetts

MC PHERSON, Stephen H.
Home:
73 Wild Hill Street
Jamaica Plain, Mass.

MC SHEEHY, William H.
Home:
475 Hill Street
Whitinsville, Mass.
Business:
Airborne Instruments Lab.
160 Old Country Road
Mineola, L.I., New York

MABLE, Robert
Home:
41 Mitchell Avenue
Binghamton, New York
Business:
Security Mutual Life
Insurance Company
Security Mutual Building
Suite 210
Binghamton, New York

MACK, Robert P.
Home:
353 Massachusetts Avenue
Cambridge, Massachusetts

MAHER, James
Home:
18 Doble Avenue
Medford, Massachusetts

MAINS, MacDonald C.
Home:
14 Brookview Road, RFD #1
Churchville, New York
c/o W. G. Mains
Business:
U.S. Navy Technical Mission
to Japan
Tokyo, Japan
c/o Postmaster
San Francisco, California

MALEY, John T.
Home:
37 Lewis Street
Newton, Massachusetts

MALLES, Ralph E.
Business:
Chief Engineer, Ditto, Inc.
Harrison at Oakley Blvd.
Chicago 12, Illinois

MANNING, Laurence A.
Home:
649 Alvarado Row
Stanford University, Calif.
Business:
Physics Department
Stanford University, Calif.

MANSFIELD, Wendell A.
Home:
Hotel Green
Danbury, Connecticut
Business:
Bard-Parker Co., Inc.
Danbury, Connecticut

MARGOLIN, Joseph
Home:
222 Seventh Street, Apt. 34
Garden City, New York
Business:
Airborne Instruments Lab.
160 Old Country Road
Mineola, L.I., New York

MARSHALL, James R.
Home: (Temporary)
32 Sylvan Avenue
Chelmsford, Massachusetts
Business:
Dielectric Products Co., Inc.
125 Virginia Avenue
Jersey City, New Jersey

MARSTON, Earle L.
Home:
1 Main Street
Milford, Massachusetts
Business:
Barber Coleman Company
Alexander Street
Framingham, Massachusetts

MARTIN, Edward G.
Home:
50 Follen Street, Apt. 505
Cambridge, Massachusetts
Business:
Radiation Laboratory, MIT
Cambridge, Massachusetts

MARTIN, Emily
(See Pound)

MARTIN, Walter J.
Home:
87 Fayerweather Street
Cambridge, Massachusetts

23.

MASON, George W.
Home:
1431 Cambridge Street
Cambridge, Massachusetts
Business:
ATSC(Cambridge Field Station)
230 Albany Street
Cambridge, Massachusetts

MASON, William A.
Home:
836 Forest Avenue
Palo Alto, California
Business:
Stanford University
Palo Alto, California

MASSEY, George H.
Home:
159 Cambridge Street
Allston, Massachusetts

MASTRIANI, Joseph W.
Home:
41-16 25th Avenue
Long Island City, New York

MAYBERRY, Leonard A.
Business:
The Hallicrafters Company
2611 S. Indiana
Chicago, Illinois

MAYNARD, Fred W.
Home:
1137 Main Street
Waltham, Massachusetts
Business:
Eastern Company
620 Memorial Drive
Cambridge, Massachusetts

MEAD, Dorothea P.
Home:
303-E Holden Green
Cambridge, Massachusetts

MEANOR, Marilene
Home:
83 Valentine Road
Arlington, Massachusetts
Business:
ATSC(Cambridge Field Station)
230 Albany Street
Cambridge, Massachusetts

MEDAK, Walter H.
Home:
40 Kirkland Street
Cambridge, Massachusetts

MEEK, Helen
Home:
10 Waldo Avenue
Somerville 43, Massachusetts

MEHNE, Ferdinand E.
Home:
2 West Street
Quincy 69, Massachusetts

MELANSON, Theodore
Home:
294 Prospect Street
Cambridge, Massachusetts

MELBYE, Margaret J. C.
Home:
19 Wendell Street
Cambridge, Massachusetts
Business:
Retail Trade Board
80 Federal Street
Boston, Massachusetts

MENUT, Eleanor S.
Home:
19 Chauncy Street
Cambridge, Massachusetts
Business:
Photoswitch, Inc.
77 Broadway
Cambridge, Massachusetts

MERCHANT, Harry A.
Home:
143 Washington Street
Reading, Massachusetts

MEREDITH, Carolyn A.
Home:
172 Park Street
Newton, Massachusetts
Business:
General Radio Company
275 Massachusetts Avenue
Cambridge, Massachusetts

MEYER, Hope M.
Home:
107 Washington Avenue
Cambridge, Massachusetts
Business:
ATSC(Cambridge Field Station)
230 Albany Street
Cambridge, Massachusetts

MIDDLETON, David
Home:
51 Brattle Street, Apt. 31
Cambridge 38, Massachusetts

MILLER, Edwin W.
Home:
U.S. Merchant Marine
300 South Broadway
Tarrytown, New York

MIMNO, Prof, H. R.
Home:
83 Pleasant Street
Lexington, Massachusetts

MIMNO (Continued)
Business:
Division 13 Communications
Laboratory
Harvard University
Cambridge, Massachusetts

MINOT, Herbert P.
Home:
85 Orchard Street
Belmont 78, Massachusetts

MITCHELL, John K.
Home:
187 Greenwood Avenue
East Orange, New Jersey

MIXEN, Carlton A.
Home:
436 Webster Street
Needham Heights, Mass.
Business:
Submarine Signal Company
160 State Street
Boston, Massachusetts

MOAKLER, Beatrice T.
Home:
1132 Massachusetts Avenue
Cambridge, Massachusetts
Business:
ATSC(Cambridge Field Station)
230 Albany Street
Cambridge, Massachusetts

MONROE, Robert B.
Home:
279 Summit Avenue
Mt. Vernon, New York
Business:
Columbia Broadcasting System
485 Madison Avenue
New York, New York

MONTGOMERY, A. Peers
Home:
5515 Wissahickon Avenue
Philadelphia, Pennsylvania
Business:
Philco Radio & Television
Philadelphia, Pennsylvania

MOORE, Thomas E.
Home:
1908 Sabine Street
Austin, Texas
Business:
Chemistry Department
332 Chemistry Building
University of Texas
Austin, Texas

B.3 List of firms from Thomson Register

Table B.2: All firms listed in Thomas Register, 1947-1956

	Number of:			Listed in TRAM?			
Firm	States	Cities	Categories	1947	1950	1953	1956
A.R.F. Products, Inc.	1	1	1			Y	
Ace Coil & Electronics Co.	1	1	1			Y	Y
Acme Electronics, Inc.	1	1	1			Y	
Aero-Rad Corp.	1	1	1	Y	Y	Y	Y
Aerovox Corp.	2	2	1	Y	Y		Y
Air Associates, Inc.	1	1	1			Y	
Airborne Instruments Laboratory, Inc.	1	1	1				Y
Aircraft Armaments, Inc.	1	1	1				Y
Airplane & Marine Instruments, Inc.	1	1	1	Y	Y	Y	Y
Airtron, Inc.	1	1	1			Y	Y
Al-Fin Corp.	1	3	1	Y	Y	Y	Y
Allied Allegri Machine Co., Inc.	1	1	1			Y	Y
Alloy Machine & Tool Co.	1	1	1		Y	Y	Y
Alox Mfg. Co.	1	1	3				Y
Altair Machinery Corp.	1	2	1		Y	Y	Y
Altec Lansing Corp.	1	1	1		Y	Y	
American Copper Sponge Co., Inc.	1	1	1				Y
American Machine & Foundry Co.	1	1	1			Y	Y
American Phenolic Corp.	1	1	1	Y	Y	Y	Y
Argus Mfg. Co.	1	1	1			Y	Y
Aronson Machine Co.	1	1	1				Y
Attic Lansing Corp.	1	1	1				Y
Autel Electronics Co.	1	1	1			Y	
Aviation Maintenance Corp.	1	1	1		Y		
Avion Instrument Corp.	2	2	1		Y	Y	Y
Barlow Engineering Co.	1	1	1		Y		
Bendix Aviation Corp.	2	2	1		Y	Y	Y
Biddle, James G. Co.	1	1	1	Y	Y	Y	Y
Bird Electronic Corp.	1	1	1	Y	Y	Y	
Black Industries	1	1	1	Y			
Bogart Mfg. Corp.	1	1	1				Y
Bone Engineering Corp.	1	1	1	Y	Y	Y	Y
Brilhart Plastics Corp.	1	1	1			Y	Y
Brown Bros. Mfg. Corp.	1	2	1			Y	Y
Brubaker Mfg. Co., Inc.	1	1	1			Y	Y
Bruno-New York Industries Corp.	1	1	1				Y
Budd-Stanley Co., Inc.	1	1	1				Y
Buehler, Inc.	1	1	1	Y	Y		
C.G.S. Laboratories, Inc.	1	1	2			Y	
Camfield Fiberglass Plastics, Inc.	1	1	1				Y
Campbell Electric Co.	1	1	1	Y			
Canoga Corp.	1	1	1				Y
Chatham Electronics, Inc.	1	2	1			Y	Y
Chemalloy-Electronics Corp.	1	1	1				Y
Christiansen, C. B. Co.	1	1	1				Y
Co-operative Industries, Inc.	1	1	1		Y	Y	Y
Conrad & Moser	1	1	1			Y	Y
Cramer, R. W. Co.	1	1	1	Y	Y		Y
Cubic Corp.	1	1	1				Y
Dalmo Victor Co.	1	1	1		Y	Y	Y
Daunt Corp.	1	1	1	Y			
Daystrom Instrument Hilltop	1	1	1				Y
De Morner-Bonardi, Inc.	1	1	1				Y
De-Mornay-Budd, Inc.	1	1	1		Y		
Dial Screw Products Co., Inc.	1	1	1			Y	
Diamond Microwave Corp.	1	1	1				Y
Dormitzer Electric & Mfg. Co., Inc.	1	2	1			Y	Y
Douglas Microwave Co., Inc.	1	1	1				Y
Du Mont Laboratories	1	1	2			Y	Y
Duncan C. L.	1	1	2				Y

Table B.2: All firms listed in Thomas Register, 1947-1956

	Number of:			Listed in TRAM?			
Firm	States	Cities	Categories	1947	1950	1953	1956
Duro Metal Spinning Co.	1	1	1			Y	Y
Edo Corp.	1	1	1				Y
Electro Impulse Laboratory, Inc.	1	1	1			Y	Y
Electronic Associates, Inc.	1	1	1		Y	Y	
Electronic Signal Co.	1	1	1		Y		
Emerson Radio and Phonograph Corp.	1	1	1	Y			
Empire State Laboratories, Inc.	1	1	1				Y
Essex Wire Corp.	1	1	1				Y
Excelco Developments, Inc.	1	1	3			Y	Y
F-R Machine Works	1	1	1		Y	Y	Y
Fairchild Engine and Airplane Corp.	1	1	1				Y
Falstrom Company	1	1	1			Y	Y
Farnsworth Electronics Co.	1	1	3				Y
Federal Telecommuincation Labratories, Inc.	1	2	1	Y	Y	Y	Y
Federal Telephone & Radio Corp.	1	1	1	Y			
Ferro-Co Corp.	1	1	1	Y	Y	Y	Y
Formcraft Tool Co.	1	1	1				Y
Frequency Standards Corp.	1	1	1			Y	
Fugle-Miller Laboratories	1	1	1		Y	Y	Y
G. & M. Equipment Co., Inc.	1	1	1				Y
Gar Precision Parts, Inc.	1	1	1			Y	Y
General Communication Co.	1	1	1	Y	Y	Y	Y
General Control Co.	1	1	1	Y	Y	Y	Y
General Dynamics Corp.	1	1	1				Y
General Electric Co.	1	1	1	Y	Y	Y	
Geophysical Service, Inc.	1	1	1		Y	Y	
Gibbs Mfg. & Research Corp.	1	1	1				Y
Gilfillan Bros., Inc.	1	1	1	Y	Y		
Graham Mfg. Co., Inc.	1	1	1			Y	Y
Gray Mfg. Co.	1	1	1		Y	Y	Y
Harvey-Wells Communications, Inc.	1	1	1	Y			
Hiliyer Instrument Co.	1	1	1				Y
Hindle Transformer Co., Inc.	1	1	1			Y	Y
Hoffman Radio Corp.	1	1	1	Y			
Honeycomb Co. of America, Inc.	1	1	1				Y
Honeycomb Strucutres Co., Inc.	1	1	1				Y
Houston Corp.	1	1	1			Y	Y
Hycon Electronics, Inc.	1	1	1				Y
I-T-E Circuit Breaker Co.	1	1	1	Y	Y	Y	Y
Imperial Machine & Tool Co.	1	1	1			Y	Y
Industrial Products Co.	1	1	1	Y	Y	Y	Y
Instrument Electronics	1	2	1	Y	Y		
International Electronic Laboratories	1	1	1	Y			
JVM Engineering	1	1	1				Y
Kahn & Co., Inc.	1	1	1			Y	Y
Karl, William & Sons	1	1	1				Y
Kay Electric Co.	1	1	1			Y	Y
Kent, F.C. Co.	1	1	1		Y	Y	Y
Kett Corp.	1	1	3				Y
Kin-E-Matic Machine Eng. Co.	1	1	1	Y	Y		
King Gun Sight Co., Inc.	1	1	1			Y	Y
Kings Electronics Co., Inc.	1	2	1	Y	Y	Y	Y
Kosempel Mfg. Co.	1	1	1				Y
Laboratory for Electronics, Inc.	1	1	1				Y
Lavoie Laboratories	1	1	1	Y	Y		Y
Lear, Inc.	2	2	1			Y	Y
Leonard Electric Products Co., Inc.	1	1	1				Y
Leonards Precision Mfg. Co., Inc.	1	1	1				Y
Leru Laboratories, Inc.	1	1	1				Y
Levinthal Electronic Products, Inc.	1	1	1				Y
Lieco, Inc.	1	1	1				Y
Lorentzen, H.K., Inc.	1	1	1			Y	
Lunn Laminates, Inc.	1	1	1			Y	
Madison Electrical Parts Corp.	1	1	1	Y			
Magnetic Research Corp.	1	1	2			Y	Y

Table B.2: All firms listed in Thomas Register, 1947-1956

	Number of:			Listed in TRAM?			
Firm	States	Cities	Categories	1947	1950	1953	1956
Manson Laboratories	1	1	1				Y
Maryland Etching Co., Inc.	1	1	1			Y	Y
Matisse Bros., Inc.	1	1	1			Y	Y
Measurements Corp.	1	1	1	Y	Y	Y	Y
Melspar, Inc.	1	1	1			Y	Y
Meridian Metalcraft, Inc.	1	1	1				Y
Metal Fabricators Corp.	1	1	2				Y
Metal Textile Corp.	1	2	1	Y		Y	Y
Micro Wave Equipment Co.	1	1	1		Y		
Microwave Development Laboratories, Inc.	1	1	2			Y	Y
Midwest Mfg. Co.	1	1	1			Y	
Missouri Research Laboratory, Inc.	1	1	1				Y
N.R.K. Mfg. & Engineering Co.	1	1	1				Y
Nassau Screw Machine Products Corp.	1	1	1				Y
National Aeronautical Corp.	1	1	1				Y
National Electrical Machine Shosp, Inc.	1	1	1			Y	
National Organ Supply Co.	1	1	1	Y			
Neptune Electronics Co.	1	1	1			Y	Y
Network Mfg. Co.	1	1	1			Y	Y
Nichols Products Co.	1	1	1		Y	Y	Y
Nosco Plastics, Inc.	1	1	1				Y
Owens Henry & Co. Corp.	1	1	1				Y
Pabst Engineering Equipment Co., Inc.	1	1	1			Y	Y
Pacific Electronics	2	2	1	Y	Y	Y	
Pedler Co.	1	1	1			Y	
Peerless Instrument Co.	1	1	1			Y	
Pem Machine Tool Co., Inc.	1	1	1				Y
Peters, O. S. Co.	1	1	1		Y	Y	Y
Petroff, Peter A.	1	1	1		Y	Y	Y
Philadelphia Metal Stamping Co.	1	1	1				Y
Philco Corp.	1	1	1	Y	Y	Y	Y
Pickard & Burns, Inc.	1	1	1				Y
Polarad Electronics Co.	1	2	1	Y	Y	Y	
Pollak & Skan, Inc.	1	1	1			Y	
Precision Apparatus Co., Inc.	1	1	1	Y	Y	Y	Y
Premier Crystal Laboratories, Inc.	1	1	1	Y	Y	Y	Y
Premier Instrument Corp.	1	1	1				Y
Pressed & Welded Steel Products Co., Inc.	1	1	1	Y	Y		
R. S. Electronics Corp.	1	1	2				Y
Racker Jos Co., Inc.	1	1	1				Y
Radiation, Inc.	1	1	1				Y
Radio Cores, Inc.	1	1	1			Y	Y
Radio Corp. of America	1	1	1				Y
Radiomarine Corp. of America	1	1	1		Y	Y	Y
Raytheon Mfg. Co.	1	1	1	Y	Y	Y	Y
Reisner WH Mfg. Co.	1	1	1				Y
Resdel Engineering Corp.	1	1	1				Y
Riverside Plastic Corp.	1	1	1				Y
Rosenberg, Paul & Associates	1	2	2		Y	Y	Y
Sanders Associates, Inc.	2	2	1			Y	Y
Schacht Steel Construction Co.	2	2	1	Y	Y		
Schutter, Carl W. Mfg. Co.	1	1	1			Y	Y
Selectar Industries, Inc.	1	1	1				Y
Servo Corp. of America	1	1	1		Y		
Skiatron Electronics & Television Co.	1	1	1				Y
Smith, J. & H. Mfg. Co.	1	1	2				Y
Special Machine Tool Engineering Works	1	1	1	Y	Y	Y	
Speciality Engineering & Electronics Co.	1	1	1				Y
Sperry Gyroscope Co., Inc.	1	1	1	Y	Y	Y	Y
Spitz Laboratories	1	1	1		Y	Y	Y
Sprague Electric Co.	1	1	1	Y	Y	Y	Y
St. Louis Radio Engineering Co.	1	1	1	Y	Y	Y	Y
Steiner, Cyrille, Inc.	1	1	1	Y			
Stelma, Inc.	1	1	2			Y	Y
Sterling Precision Instrument Corp.	1	1	1				Y

Table B.2: All firms listed in Thomas Register, 1947-1956

Firm	Number of: States	Cities	Categories	Listed in TRAM? 1947	1950	1953	1956
Suffolk Products Corp.	1	1	1			Y	Y
Sylvania Electric Products, Inc.	1	1	1	Y			
TAB	1	1	1			Y	Y
Tech-Tron Corp.	1	1	1				Y
Technical Appliance Corp.	1	1	1			Y	Y
Technicraft Laboratories	1	1	2			Y	Y
Telechrome Mfg. Corp.	1	1	1			Y	Y
Telectro Industries Corp.	1	1	1			Y	Y
Telerad Mfg. Corp.	1	1	2		Y	Y	Y
Television Equipment Corp.	1	1	2			Y	
Texas Instruments, Inc.	1	1	1				Y
Titeflex, Inc.	2	2	1			Y	Y
Torngren CW Co., Inc.	1	1	1				Y
Transmitter Equipment Mfg. Co., Inc.	1	2	1	Y	Y	Y	Y
Tudor Products Co.	1	2	1	Y	Y		
U.S. Electronics Corp.	1	1	1		Y	Y	
Ultrasonic Corp.	1	1	1				Y
Underwood Electric & Mfg. Co.	1	1	1	Y	Y	Y	Y
Vectron, Inc.	1	1	2				Y
Vee-Day Instrument & Machine Corp.	1	1	1				Y
Vibro Mfg. Co., Inc.	1	1	2		Y	Y	Y
Virginia Electronics Co.	1	1	1				Y
Waldorf Instrument Corp.	1	1	1				Y
Washington Aluminum Co., Inc.	1	1	1				Y
Waveline, Inc.	1	2	1			Y	Y
Webster Chicago Corp.	1	1	2				Y
Welded Products, Inc.	1	1	1				Y
Westinghouse Electric Corp.	1	1	1	Y	Y	Y	Y
Westline Crystal Co.	1	1	1	Y			
Wheeler Laboratories	1	1	1			Y	Y
Wilmar Products, Inc.	1	1	1			Y	
Zenith Plastics Co.	1	1	1			Y	Y

Notes: Table lists all radar manufacturing firms in the 1947 to 1956 editions of the Thomson Register.

C Supplementary Results

C.1 Characteristics of Rad Lab researchers

We first use our data to document several characteristics of the Rad Lab and RRL, examining both their operations and and their output. Table C.1, provides descriptive statistics for the 1,362 Rad Lab staff listed in the technical roster. Nearly half of this staff was physical scientists, and one third engineers. Over a quarter had a PhD, whereas half had a bachelor's degree—including a large number of recent college graduates and graduate students who effectively worked as applied research assistants. One-sixth of this roster (216 of 1,362) produced a patented, Rad Lab invention. Though we lack comparable biographical data for the RRL, contemporary records indicate it was smaller but similar in composition and productivity (Figure A.4 shows headcount peaked at 800, versus the Rad Lab's nearly 4,000, with a technical staff of 200). Table C.2 lists the top 10 postwar industry employers of Rad Lab and RRL researchers.

Table C.1: Descriptive statistics for Rad Lab staff and RL/RRL patents

Variable	N	Mean	P10	P25	P50	P75	P90
Physical Scientist	1362	0.49	0	0	0	1	1
Engineer	1362	0.34	0	0	0	1	1
Highest degree: PhD	1122	0.28	0	0	0	1	1
Highest degree: MA	1122	0.17	0	0	0	0	1
Highest degree: BA	1122	0.56	0	0	1	1	1
Degree year	1122	1937.36	1929	1935	1940	1942	1943
Has Rad Lab patent	1362	0.16	0	0	0	0	1
Num. Rad Lab patents, if any	216	2.38	1	1	1	3	6
RL/RRL patents' filing year	588	1944.98	1944	1945	1945	1945	1946
RL/RRL patents' forward citations	588	6.01	0	2	4	8	13

Notes: This table provides summary statistics for assorted characteristics of the Rad Lab staff in our data (top rows) and for Rad Lab/RRL patents (bottom rows).

Table C.2: Top 10 industry employers of RL/RRL alumni

Rad Lab (MIT)		RRL (Harvard)	
	Count		Count
IBM Watson Laboratories	33	Airborne Instrument Laboratory	26
General Precision	20	Columbia Broadcasting System	15
General Electric	13	Raytheon Mfg. Co.	9
Bell Telephone Labs	12	Submarine Signal Co.	8
Self-Employed	12	General Electric	7
DuMont Laboratories	10	Bell Telephone Labs	6
Philco Corp.	10	Holtzer-Cabot Electric Co.	5
Eastman Kodak Co.	9	General Radio Co.	5
Airborne Instrument Laboratory	9	Radio Corp. of America	4
Sperry Gyroscope	8	Photoswitch, Inc.	4

Notes: This table lists the top 10 industry employers of Rad Lab and RRL staff, where known.

C.2 Operational characteristics of the Rad Lab and RRL

Here we provide additional evidence into the nature of Rad Lab (and RRL) R&D, what made it distinctive, and the ways in which its collaborative structures persisted beyond the end of the war. We show that the Rad Lab brought together researchers without previous collaborative ties, who were otherwise unlikely to work together. Rad Lab patents were not only were more novel, collaborative, and impactful than contemporary invention in the same classes (Table 4) but also involved more diverse inventor teams. We also show that Rad Lab staff were more likely to continue co-inventing with colleagues they worked closely with during the war.

C.2.1 Characteristics of RL/RRL invention

Table C.3 explores whether Rad Lab/RRL patents had more or less technologically diverse inventor teams than contemporary collaborative patents. Our estimation sample consists of co-inventor pairs on multi-inventor patents filed in the same years as Rad Lab/RRL patents (1943-1946), where both inventors in the pair also had pre-war patents, which we use to characterize prior inventive activity. We measure homophily in three ways. In Panel (A) we measure the similarity of co-inventors with respect to their pre-war patent classes, calculated as the fraction of the patent classes of their 1930s patents that they share in common. In Panel (B) we analogously measure similarity with respect to pre-war patent keywords. Finally, in Panel (C) we measure shared industry experience, vis-à-vis pre-war patents with a firm assignee. We estimate large reductions in inventor homophily on Rad Lab/RRL patents, roughly equal to the mean value in the full sample.

Table C.4 provides contextual evidence suggesting implications of this result, estimating the relationship between patents' forward citations and co-inventor homophily across this sample (patents filed between 1943 and 1946 with multiple inventors with pre-war patents). The table shows that more dissimilar co-inventors produce more highly-cited patents, particularly when the homophily of the pair is measured on their technological backgrounds.

Table C.3: Similarity of co-inventors on RL/RRL patents vs. others

Panel A: Similarity of principal pre-war patent classes

	(1)	(2)	(3)	(4)
1(Is RL/RRL patent)	-0.065***	-0.058***	-0.053***	-0.047***
	(0.002)	(0.003)	(0.006)	(0.008)
N	19177	19177	19160	19024
R^2	0.00	0.01	0.07	0.13
Filing year FEs		Y		
Class FEs			Y	
Class-year FEs				Y
Y mean	0.07	0.07	0.07	0.07

Panel B: Similarity of principal words in pre-war patents

	(1)	(2)	(3)	(4)
1(Is RL/RRL patent)	-0.078***	-0.070***	-0.067***	-0.057***
	(0.003)	(0.003)	(0.007)	(0.008)
N	19168	19168	19151	19015
R^2	0.00	0.01	0.09	0.16
Filing year FEs		Y		
Class FEs			Y	
Class-year FEs				Y
Y mean	0.09	0.09	0.09	0.09

Panel C: Similarity vis-à-vis pre-war industry experience

	(1)	(2)	(3)	(4)
1(Is RL/RRL patent)	-0.230***	-0.214***	-0.206***	-0.189***
	(0.018)	(0.019)	(0.022)	(0.026)
N	25125	25125	25117	24989
R^2	0.00	0.02	0.06	0.12
Filing year FEs		Y		
Class FEs			Y	
Class-year FEs				Y
Y mean	0.28	0.28	0.28	0.28

Notes: Table estimates differences in the similarity of co-inventors on Rad Lab/ RRL patents relative to others. Observations are pairs of co-inventors on U.S. patents filed between 1943 and 1946. Panel (A) measures the similarity of co-inventors with respect to their pre-war patent classes, calculated as the fraction of the patent classes of their 1930s patents that they share in common. Panel (B) measures similarity with respect to pre-war patent keywords, calculated as the fraction of the keywords of their 1930s patents that they share in common. Panel (C) measures similarity with respect to industry experience, calculated as having any 1930s patent with a firm assignee. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by patent in parentheses.

Table C.4: Quality of patents produced by diverse inventor teams

Panel A: Similarity of principal pre-war patent classes

	(1) Num. citations	(2) Any citations	(3) ≥5 citations	(4) ≥10 citations	(5) ≥20 citations
Similarity	-1.093***	-0.067***	-0.072***	-0.047***	-0.020***
	(0.271)	(0.019)	(0.024)	(0.015)	(0.007)
N	15803	15803	15803	15803	15803
R^2	0.14	0.11	0.12	0.11	0.09
Class-year FEs	Y	Y	Y	Y	Y
Y mean	4.67	0.85	0.36	0.13	0.03

Panel B: Similarity of principal words in pre-war patents

	(1) Num. citations	(2) Any citations	(3) ≥5 citations	(4) ≥10 citations	(5) ≥20 citations
Similarity	-0.796***	-0.087***	-0.066***	-0.035**	-0.010
	(0.282)	(0.019)	(0.023)	(0.015)	(0.008)
N	15797	15797	15797	15797	15797
R^2	0.14	0.11	0.12	0.11	0.09
Class-year FEs	Y	Y	Y	Y	Y
Y mean	4.67	0.85	0.36	0.13	0.03

Panel C: Similarity vis-à-vis pre-war industry experience

	(1) Num. citations	(2) Any citations	(3) ≥5 citations	(4) ≥10 citations	(5) ≥20 citations
Similarity	0.004	-0.009	-0.000	-0.002	-0.001
	(0.100)	(0.006)	(0.008)	(0.006)	(0.003)
N	20312	20312	20312	20312	20312
R^2	0.12	0.10	0.11	0.09	0.07
Class-year FEs	Y	Y	Y	Y	Y
Y mean	4.62	0.85	0.36	0.12	0.02

Notes: This table estimates differences in forward citations of patents with more versus less similar co-inventors. Observations are pairs of co-inventors on U.S. patents filed between 1943 and 1946. Panel (A) measures the similarity of co-inventors with respect to their pre-war patent classes, calculated as the fraction of the patent classes of their 1930s patents that they share in common. Panel (B) measures similarity with respect to pre-war patent keywords, calculated as the fraction of the keywords of their 1930s patents that they share in common. Panel (C) measures similarity with respect to industry experience, calculated as having any 1930s patent with a firm assignee. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by patent in parentheses.

C.2.2 Evidence of persistent collaborations

In Section 2 we described how the Rad Lab (and RRL) was organized into divisions, comprised of working groups, composed of individuals working together as lab teams. Appendix Figure A.3 illustrates the workshop environment that characterized much of the Rad Lab's R&D operations. Qualitative histories suggest that this environment bred close working relationships (Massachusetts Institute of Technology 1946). We next show that collaborative relationships developed at the Rad Lab and RRL extended beyond organizational boundaries, and persisted.

As before, we do so primarily by examining co-invention patterns, focusing on non-OSRD patents (i.e., patents that are not attributable to a wartime OSRD contract, per). We estimate differences in the likelihood that two inventors (ever) co-invented a non-OSRD patent as a function of their wartime working relationship, in a set of potential candidate inventor pairs. Our sample consists of pairs of Rad Lab/RRL staff who were actively inventing in the same NBER technology category (Hall et al. 2001) within two years of each other—not all of whom co-invented, though some did. The results of these tests are in Table C.5. Across columns, we estimate differences in the propensity to co-invent as a function of whether the two individuals in each candidate pair worked in (1) the same lab (Rad Lab vs. RRL), (2) the same division, or (3) the same group; whether they (4) co-invented a Rad Lab/RRL patent; and (5) the number of years they overlapped at the Rad Lab (Rad Lab staff only, for whom we have these data). Column (6) provides a horserace regression. All columns include individual fixed effects and robust standard errors, though the results are consistent with dyadic clustering. We find that the likelihood of co-invention increases sharply with the intimacy of the wartime co-working relationship. In the horserace regression—where the sample is restricted to pairs of Rad Lab staff only—we find quantitatively similar patterns for most categories of wartime collaboration, albeit with larger standard errors.

In Table C.6, we disaggregate these data into three periods (eight year intervals from 1933 to 1956, as before) to examine how co-invention patterns varied over time vis-à-vis candidate co-inventors' wartime collaboration. Though standard errors increase due to reduced power in each estimated cell, we discern a few patterns. First, we find no statistically significant relationship between wartime collaboration and pre-war co-invention—of which there was, in this group, approximately none. Second, it appears that much of the effect in Table C.5 is generated by non-OSRD invention in or around the war years. We also find quantitatively large, persistent effects of wartime collaboration into the postwar period—generally as large or larger than the estimated effects on mid-war co-invention—but these differences are in some cases statistically significant (Columns 1 and 5), and other cases too imprecise to reject the null (Columns 2 to 4).

In Table C.7, we show that postwar employment patterns may be one mechanism through which these results operate. Individuals who worked together during the war—at the same lab, division, working group, or even on the same patent—were more likely to place at the same employer or institution, indicating that some staff were hired together. That the magnitudes of these effects decline with co-working proximity suggest this may be more a byproduct of organizational context and lab-level placement networks than specific staff relationships.

Figure C.1 visualizes the co-invention network among Rad Lab and RRL staff members, first for OSRD patents (Panel A) and then for non-OSRD patents, in five year intervals from the 1940s onwards (Panels B to E; we omit the pre-1940 period, which has only one co-inventing pair). The persistence of collaborative ties among Rad Lab and RRL researchers is visible across all periods, albeit with decay, with only a few ties persisting to 1960.

Table C.5: Pr(Pair ever collaborated on a non-OSRD patent) (x100)

	(1) Same lab	(2) Same division	(3) Same group	(4) Same patent	(5) Years overlapped	(6) Horserace
Same lab	0.369***					
	(0.102)					
Same division		1.073***				0.368
		(0.258)				(0.230)
Same group			2.308***			1.736**
			(0.651)			(0.708)
Same patent				5.086**		4.377
				(2.343)		(2.686)
Years overlapped					0.193**	0.166*
					(0.087)	(0.086)
N	25755	25755	25755	25755	16453	16453
R^2	0.03	0.03	0.03	0.03	0.03	0.04
Y mean	0.179	0.179	0.179	0.179	0.249	0.249

Notes: This table estimates differences in the likelihood that two Rad Lab/RRL staff members co-invented a non-OSRD patent, as a function of whether they worked (1) in the same lab (RL or RRL), (2) in the same Rad Lab division, (3) in the same Rad Lab working group; whether they (4) co-invented an OSRD patent; if both at Rad Lab, (5) the number of years they overlapped; and (6) a horserace regression between them. Observations are pairs of Rad Lab/RRL staff who were actively inventing in the same broad NBER technology category (Hall et al. 2001) within two years of each other, whom we consider candidates for co-invention. All columns include fixed effects for each person in the pair. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. Robust SEs in parentheses.

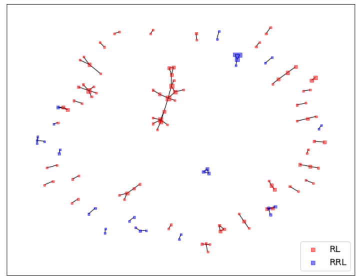
Table C.6: Pr(Pair collaborated on a non-OSRD patent in given period) (x100)

	(1) Same lab	(2) Same division	(3) Same group	(4) Same patent	(5) Years overlapped	(6) Horserace
Same lab * 1(1933-1940)	0.458					
	(0.439)					
Same lab * 1(1941-1948)	0.273***					
	(0.086)					
Same lab * 1(1949-1956)	0.633***					
	(0.172)					
Same division * 1(1933-1940)		-0.195				0.054
		(0.231)				(0.162)
Same division * 1(1941-1948)		0.981***				0.401*
		(0.250)				(0.228)
Same division * 1(1949-1956)		0.891				0.131
		(0.667)				(0.639)
Same group * 1(1933-1940)			-0.409			-0.306
			(0.408)			(0.411)
Same group * 1(1941-1948)			2.032***			1.502**
			(0.616)			(0.687)
Same group * 1(1949-1956)			1.936			1.090
			(1.737)			(1.592)
Same patent * 1(1933-1940)				0.000		0.000
				(.)		(.)
Same patent * 1(1941-1948)				4.104*		3.201
				(2.128)		(2.404)
Same patent * 1(1949-1956)				6.539		6.744
				(6.890)		(7.687)
Years overlapped * 1(1933-1940)					0.192	0.196
					(0.149)	(0.148)
Years overlapped * 1(1941-1948)					0.158**	0.134*
					(0.076)	(0.076)
Years overlapped * 1(1949-1956)					0.442**	0.420**
					(0.185)	(0.173)
N	29098	29098	29098	29098	18461	18461
R^2	0.02	0.03	0.03	0.03	0.03	0.04
Y mean	0.172	0.172	0.172	0.172	0.244	0.244

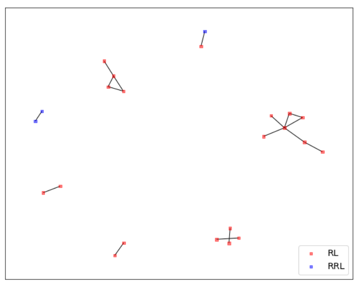
Notes: This table estimates differences in the likelihood that two Rad Lab/RRL staff members co-invented a non-OSRD patent in the pre-, mid-, and post-war periods, as a function of whether they worked (1) in the same lab (RL or RRL), (2) in the same Rad Lab division, (3) in the same Rad Lab working group; whether they (4) co-invented an OSRD patent; if both at Rad Lab, (5) the number of years they overlapped; and (6) a horserace regression between them. Observations are pairs of Rad Lab/RRL staff who were actively inventing in the same broad NBER technology category (Hall et al. 2001) within two years of each other, whom we consider candidates for co-invention, measured in each period where they were both active. All columns include fixed effects for each person in the pair, and period fixed effects for the three periods shown. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. Robust SEs in parentheses.

Figure C.1: Collaboration networks for patents of RL and RRL inventors

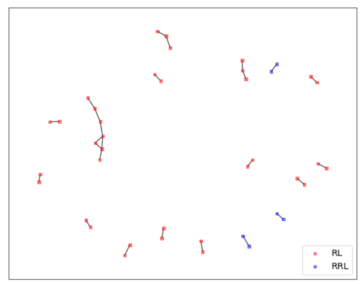
Panel (A):
OSRD patents



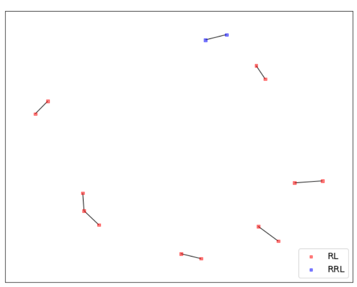
Panel (B):
Non-OSRD patents, 1940-1945



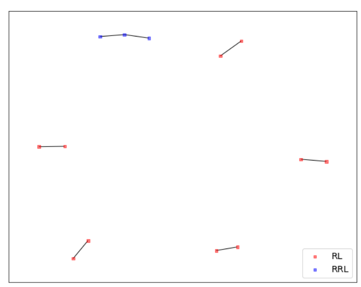
Panel (C):
Non-OSRD patents, 1946-1950



Panel (D):
Non-OSRD patents, 1951-1955



Panel (E):
Non-OSRD patents, 1956-1960



Notes: The figure illustrates co-invention networks of Rad Lab and RRL staff, first for OSRD-funded patents (Panel A) and then other other patents, in five year intervals (Panels B to E). The figure illustrates the persistence of collaborative ties among Rad Lab and RRL researchers. Pre-1940, there is only one co-inventing pair in this population.

Potential mechanism: Joint placement

In Table C.7 we estimate differences in the likelihood that two Rad Lab/RRL staff members were placed at the same employer after the war, as a function of their wartime working relationship, in a set of staff member pairs for whom placement outcomes are known. Across columns, we estimate differences in the likelihood of a joint placement as a function of whether the two individuals in each candidate pair worked in (1) the same lab (Rad Lab vs. RRL), (2) the same division, or (3) the same group; whether they (4) co-invented a Rad Lab/RRL patent; and (5) the number of years they overlapped at the Rad Lab (Rad Lab staff only, for whom we have these data). Column (6) provides a horserace regression. All columns include individual fixed effects and robust standard errors, though the results are consistent with dyadic clustering. We find that individuals who worked together, in various forms, were more likely to be jointly placed, though the magnitudes of the respective effects do not necessarily indicate that a closer wartime working relationship facilitated joint placement more than organizational context—perhaps reflecting more the distinctive networks of the Rad Lab and RRL than the relationships among their staff.

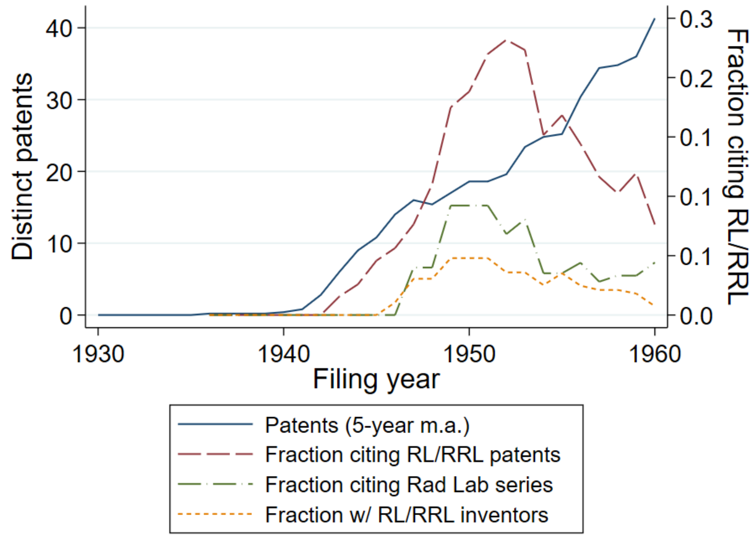
Table C.7: Pr(Inventor pair shared a post-war employer) (x100)

	(1) Same lab	(2) Same division	(3) Same group	(4) Same patent	(5) Years overlapped	(6) Horserace
Same lab	4.111***					
	(0.560)					
Same division		2.433***				2.187***
		(0.527)				(0.637)
Same group			1.989**			-0.112
			(0.935)			(1.142)
Same patent				6.681*		2.893
				(3.830)		(3.841)
Years overlapped					0.548	0.536
					(0.461)	(0.460)
N	16393	16393	16393	16393	11123	11123
R^2	0.14	0.13	0.13	0.13	0.17	0.18
Y mean	2.727	2.727	2.727	2.727	3.407	3.407

Notes: This table estimates differences in the likelihood that two Rad Lab/RRL staff members shared a common postwar employer, as a function of whether they worked (1) in the same lab (RL or RRL), (2) in the same Rad Lab division, (3) in the same Rad Lab working group; whether they (4) co-invented an OSRD patent; if both at Rad Lab, (5) the number of years they overlapped; and (6) a horserace regression between them. Observations are pairs of Rad Lab/RRL staff for whom we observe postwar placements. All columns include fixed effects for each person in the pair. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by patent in parentheses.

C.3 Growth of patenting in the microwave field

Figure C.2: RL/RRL-produced resources and firm patenting in microwave technology, 1930-1960



Notes: This figure plots the five-year rolling average of annual firm microwave patents (left axis), and the share of those patents which (i) cite Rad Lab/RRL patents, (ii) cite the Rad Lab series, and (iii) include Rad Lab/RRL alumni inventors (right axis).

Appendix references

Gross, Daniel P and Bhaven N Sampat. 2022. *America, jump-started: World War II R&D and the takeoff of the U.S. innovation system.* NBER Working Paper No. 27375.

Hall, Bronwyn H, Adam B Jaffe, and Manuel Trajtenberg. 2001. *The NBER patent citation data file: Lessons, insights and methodological tools.* NBER Working Paper No. 8498.

Harvard University. 1946. *Administrative history of the Radio Research Laboratory.*

Marco, Alan C, Michael Carley, Steven Jackson, and Amanda Myers. 2015. *The USPTO Historical Patent Data Files: Two Centuries of Innovation.* Available at https://ssrn.com/abstract=2616724.

Massachusetts Institute of Technology. 1946. *Five years at the Radiation Laboratory.*