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Bringing back the golden days of Bell Labs

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Established almost 100 years ago, Bell Labs made a great contribution to advancing both fundamental science and technology. Was that the result of a unique set of circumstances or is there a reproducible recipe for success?

If there ever was a place to rival the scientific might of national labs or organizations like CERN, it was Bell Labs. That is where information theory was born, the transistor was invented and the cosmic microwave background was discovered. It is also where the first algorithms (Shor's factorization and Grover's database search) that kindled widespread interest into quantum computing were developed. Many have wondered how an industrial lab could have had such a tremendous impact on both fundamental and applied science. Its recipe for success is now well understood, but whether it could be recreated in today's world — that is a different story.

The rise and fall of Bell Labs

A hundred years ago, a new technology was coming to the fore: telephony. In 1915, Alexander Graham Bell's American Telegraph & Telephone Company (AT&T) demonstrated the first transcontinental call, between New York and San Francisco. The breakthrough was possible thanks to the vacuum tube repeaters developed by physicist Harold D. Arnold. Arnold was one of the hundreds of scientists who, together with many more engineers and staff, were to be part of the Bell Telephone Laboratories, Inc., funded by AT&T and Western Electric in 1925. From Arnold's vacuum tubes and the establishment of Bell Labs, AT&T went on to build the infrastructure that would ensure the company's monopoly over the US long-distance telephone market for half a century.

AT&T had a clear vision, that of offering universal connectivity to its customers. To achieve this well-defined long-term goal, the company consistently invested in R&D, planning ahead in terms of decades rather than years. Thanks to its government-supported monopoly, it could also afford to maintain the long-term thinking for half a century. Bell Labs was funded by what physicist and historian of science and technology Michael Riordan called "essentially a built-in 'R&D tax' on telephone service"[1], an enviable position akin to a publicly-funded institution like CERN. The similarity runs deeper, because as in the case of CERN, Bell Labs produced both fundamental breakthroughs that changed our understanding of the Universe and technological advances that have shaped the modern world.

The achievements of the Bell Labs researchers have been recognized by nine Nobel prizes and four Turing awards, the best-known inventions being the transistor, laser, charged-coupled device and photovoltaic cell. Bell Labs was the birthplace of information theory, the UNIX operating system and C programming language. Bell Labs researchers not only made fundamental breakthroughs in understanding the electronic structure of materials and discovered new phenomena such as the fractional quantum Hall effect, but they also created new technologies that enabled great discoveries, for example radio astronomy and the discovery of the cosmic microwave background — the relic radiation from the early Universe. Other Nobel prizes recognized the importance of the development of methods that are now essential tools in many fields of research: electron diffraction, laser cooling, optical tweezers and super-resolved fluorescence microscopy.

However, AT&T "maintained its monopoly at the government's pleasure, and with the understanding that its scientific work was in the public's interest"[2] so it could not fully exploit the technology Bell Labs developed. So these very advances ultimately led to AT&T's demise, as other companies made use of the technologies. At the dawn of the Internet age and rise of mobile phone networks, after having faced an almost decade-long antitrust lawsuit, AT&T lost its monopoly in 1982 and was restructured into a number of subsidiaries. It was the end of an era and funding of Bell Labs started to dwindle. By 2008 only a handful of scientists were left[3]. In 2016, Nokia acquired Alcatel-Lucent, then the parent company of Bell Labs, which was resuscitated under the new name of Nokia Bell Labs.

The recipe for success

Riordan attributed the success of Bell Labs to the "combination of stable funding and long-term thinking"[1]. These are certainly key factors, also for big science projects. But there were other ingredients articulated in 1950 by Mervin Kelly, director of Bell Labs. Kelly's

Fig. 1 | **A view from the Bells Labs.** The photograph was taken in the Acoustics Foyer of the Bell Telephone Laboratories at Murray Hill, New Jersey in May 1942. Credit: Universal Images Group Editorial/Getty Images.

core belief was that "basic research is the foundation on which all technologic advances rest"[4]. He called the labs "an institute of creative technology" and had a very clear vision of how such an institution should be run, from the people he hired to the layout of the rooms of the building he helped design.

Like many big tech companies and start-ups today, Kelly believed that to achieve outstanding results an organization needs a critical mass of talented people with different skills. He was looking to hire men (remember this is the 1950s!) "of the same high quality as are required for distinguished pure research in universities"[5]. Attracting such talent was not a problem, rather the challenge was to create the right environment for it to thrive. "We give much attention to the maintenance of an atmosphere of freedom and an environment stimulating to scholarship and scientific research interest. It is most important to limit their work to that of research"[5]. Kelly believed that any distractions would make researchers lose "contact with the forefront of their scientific interest"[5] and decrease their productivity in research. Above all, Kelly saw research as a "non-scheduled area of work"[4], translating to no deadlines, objectives or progress reports.

Kelly was also very particular about the physical environment these bright minds would thrive in. Like Steve Jobs decades later, Kelly had a hands-on involvement in the architectural design. For the Bell Labs Murray Hill building (FIG. 1) in New Jersey Kelly devised flexible modular rooms along long corridors to accommodate offices, labs and other workspaces. This layout brought together theorists, experimentalists and technicians. The policy of keeping the office doors open fostered an atmosphere for the free exchange of ideas where newcomers could go and talk with researchers like William Shockley, one of the inventors of the transistor, or Claude Shannon, father of information theory. The Murray Hill building also had labs and machinery available to try out new things. It hosted an amazing repository of scientific and technical know-how.

Recreating the recipe

Today, building a fully-functional quantum computer with thousands of qubits seems as daunting as building a country-wide telephone network must have seemed a hundred years ago. It was clear that it was technologically possible, but not all the devices and interconnects had yet been developed. It was unclear what materials would work best, how they could operate in real-life conditions and how things could be scaled up. AT&T understood that a lot of R&D would be required, involving a huge workforce of engineers and technicians. Quantum computing is in a similar position today. Several technologies have been demonstrated, some platforms boasting over a hundred qubits, but which one will scale up best and prove to be most robust remains to be seen. Quantum computing has become primarily an engineering challenge that will require a large, highly-skilled workforce to tackle.

Is it time to revisit Kelly's lessons? Recreating his recipe for success will be challenging. In some respects, we are now better placed than Bell Labs was in its days of glory. Whereas Kelly would only hire white men, today a company can potentially hire from a larger and more diverse pool of talented people. However, there is a worldwide shortage of specialists to fill the increasing demand for a quantum workforce[6]. Bringing everyone under one roof will be difficult given the predominant trend to work remotely and have divisions in most big tech companies spread across continents, even before the changes brought by the COVID-19 pandemic.

In theory, there is a lot of money: the combined market value of the big tech companies is several trillion US dollars (USD). Some of these companies already invest 10–15% of their ever-increasing revenue (tens to over one hundred billion USD) in R&D. How much big tech, or venture capital, investment goes into quantum computing is hard to estimate, but the public-funded quantum initiatives worldwide alone could amount to ~24 billion USD. To put this in context, the total cost of the recently deployed James Webb Space Telescope was over 10 billion USD (REF.[7]), and the next generation CERN particle accelerator is estimated at around 24 billion dollars (REF.[8]). But it's hard to predict whether this level of funding will continue and for how long.

Perhaps, most importantly the freedom and time to pursue any research interest is a luxury very few scientists in academia or other research organizations can afford. Unlike Bell Labs in the past, "most industry labs today lack the freedom to pursue projects that are divorced from nearer-term commercial objectives, and the resulting knowledge is often kept proprietary"[9]. All considered, Kelly's recipe no longer seems universal and the success of Bell Labs appears to be the result of a set of unique circumstances. But perhaps one should not be so swift in discarding Kelly's lessons.

A new world

In quantum computing thinking is shifting from a government-funded big science approach to an exploration and exploitation of the more dynamic start-up innovation ecosystem. "We need to try out different things, and use the innovation ecosystem to test, learn and build machines. That's the sort of most effective path," says Jacob Taylor, former assistant director for quantum information science at the White House and one of the people behind the creation of the US National Quantum Initiative, who recently joined the UK quantum software company Riverlane. Although a start-up innovation environment is aimed at tackling engineering challenges, "there is science to be done in the start-up world," says Taylor. Considering the example of the tools that enable quantum error correction, he points out that "as you engineer a solution, a new set of research opportunities arise, that in turn drive the next round of engineering. This loop is seen throughout the tough-tech space." Taylor contends that the incentives to hire the best people and to ensure that solutions are useable can organically drive publication and disclosure, making certain that the progress is scientific, not just commercial.

In a recent Comment in *Nature*, Adam Marblestone and colleagues[9] introduced the concept of 'focused research organizations', non-profit start-ups employing full-time scientists and engineers to pursue clear milestones over longer periods than those allowed by most academic or commercial projects. Perhaps these new ideas can be married to Kelly's philosophy to create a modern research ecosystem, different, but as successful as that of Bell Labs.

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