

The Open Foundation

Quantum Technology Needs

Why Open Source Infrastructure can Accelerate a Better Quantum Future

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**Unitary
Foundation**

1. The Quantum Moment

Quantum technology is no longer a distant science project. It is a field of active engineering and accelerating capital deployment, and its strategic importance is now recognized at the highest levels of government and industry worldwide. In 2025, private investment in quantum technology surpassed \$10 billion (more than double the previous year's record) bringing cumulative global investment past \$55.7 billion. McKinsey's 2025 Quantum Technology Monitor estimates the economic value at stake from quantum computing alone at \$0.9 to \$2 trillion by 2035, driven by breakthroughs in pharmaceuticals, financial services, energy, and logistics. The White House ranked quantum technology second only to artificial intelligence on its 2025 Science and Technology Highlights. Quantum technology is now a significant focus of industrial policy across continents.

The national security implications are equally concrete. Quantum computers will eventually break the encryption that underpins global commerce, military communications, and critical infrastructure: an event the industry calls Q-Day. The CSIS Commission on U.S. Quantum Leadership warned that a quantum decryption surprise from a strategic competitor would threaten both national security and commercial communication. NIST has published post-quantum cryptography standards, but transitioning the world's digital infrastructure to these new protocols is a multi-year, multi-billion-dollar undertaking. The risk to cryptography alone, as the Commission concluded, justifies major public spending on quantum technology.¹

What makes this moment unusual is the gap between the scale of investment and the maturity of the ecosystem. Billions are flowing into quantum hardware, but the software layer remains underfunded and fragmented. We will need the compilers, benchmarking tools, error-mitigation libraries, and developer frameworks that translate hardware capability into real-world applications. We are building powerful hammers. Now we need the tools to find the most meaningful nails.

2. A Hammer Looking for Nails

The history of computing is the history of open platforms unlocking unforeseen applications. No one designing TCP/IP in the 1970s predicted e-commerce. No one writing the Linux kernel in 1991 anticipated that it would run 90 percent of the world's cloud infrastructure three decades later. The Apache HTTP Server, released freely in 1995, became the substrate of the early web economy. Openness allowed millions of builders to experiment, fail cheaply, and discover what worked. When Mozilla Foundation launched Firefox in 2004, it did more than offer an alternative browser. It broke a monopoly stranglehold on the web and proved that a non-profit, open source challenger could reshape a global technology market and defend the open internet as a public resource. The lever was not the product alone — it was Mozilla Foundation's role as a neutral steward of open standards, holding the line on interoperability when market actors would not. More

recently, open source machine learning frameworks—TensorFlow, PyTorch, scikit-learn—transformed AI from an academic discipline into a global industry. The models running on these frameworks now power products used by billions of people. None of this was planned from the top down. It emerged from the bottom up, through open infrastructure.

Quantum computing is at a strikingly similar inflection point. The hardware is advancing rapidly. Multiple platforms, from superconducting qubits to trapped ions to photonic processors, are scaling toward hundreds and eventually thousands of qubits. But the field has not yet found all its best applications. As one of us argued in *Nature* in 2017¹, the way to discover what quantum computers can do is to build the software, run the experiments, and learn empirically. Hybrid quantum-classical algorithms need to be studied the way machine learning algorithms are studied: by putting tools in the hands of many researchers and practitioners, across many domains, and letting them explore. The performance of these algorithms is often unpredictable from theory alone. You need to try them.

Open source is how you make that exploration possible at scale. When a chemist in São Paulo, a logistics researcher in Berlin, and a financial engineer in Singapore can have frictionless access to the same quantum programming tools the search for quantum advantage becomes a global, parallel effort rather than a siloed, sequential one. Open source lowers the cost of experimentation by sharing the fixed costs of infrastructure across many users. It allows researchers to build on one another's work rather than reinventing wheels behind proprietary walls.

Unitary Foundation has articulated this vision as the need for a “quantum Linux”: an open-source quantum operating system that enables hardware platforms, cloud providers, researchers, startups, and government users to interoperate through a common, trusted software foundation. Just as Linux and related open systems software catalyzed decades of innovation in classical computing, an open quantum software layer is required to translate quantum advances into scalable, secure, and economically meaningful capability. Without it, the United States and the global quantum community risk continued fragmentation, duplicated effort, and slower capability diffusion.

The economic argument is not abstract. Harvard Business School research estimates the demand-side value of open source software at \$8.8 trillion, i.e. the cost firms would bear if they had to recreate the open source code they currently use for free.² Ninety-six percent of commercial software includes open source components. The quantum field, still in its early chapters, has the opportunity to build its ecosystem on an analogous open foundation from the beginning. This is better than trying to retrofit openness later, as classical computing eventually had to do.

¹ Zeng, W., Johnson, B., Smith, R., Rubin, N., Reagor, M., Ryan, C., & Rigetti, C. (2017). First quantum computers need smart software. *Nature*, 549(7671), 149-151.

3. The Funding Gap — and Why Open Source is High Leverage

If open source quantum software is so valuable, why is it underfunded? The answer lies in a structural gap that will be familiar to anyone who has worked at the intersection of research and infrastructure. Academic grants reward papers, not maintained software. A researcher who publishes a novel algorithm gets credit; the engineer who builds and maintains the compiler that makes it usable across three hardware platforms does not. Traditional Federal science funding is designed to push the frontiers of knowledge, but it is poorly suited to the unglamorous but essential work of software maintenance, documentation, testing, and community governance. On the other side, venture capital funds companies with products and paths to revenue. Open source infrastructure projects are not companies. They do not have customers. They have users—often thousands of them—but no product to sell and no equity to return. These projects fall between the cracks.

Yet open source projects are the shared substrate on which both academic research and commercial applications depend. The error-mitigation library that a pharmaceutical company uses to run molecular simulations is the same one a graduate student uses to benchmark a new algorithm. The compiler collection that a defense contractor relies on for quantum circuit optimization is maintained by the same small team that serves a startup's needs. This is the nature of infrastructure: it is most valuable precisely when it is not owned by any single party.

History offers a clear precedent. Early federal and philanthropic investment in internet protocols, high-performance computing software, and foundational open source projects was disproportionately impactful because it created public goods that everyone could build on. The U.S. government's sustained investment in HPC, from the 1950s through the NITRD program and beyond, was driven first by national security and then by the recognition that shared computing infrastructure accelerated both scientific discovery and commercial competitiveness. The CSIS Commission on Quantum Leadership draws exactly this parallel, noting that federal funding for HPC was crucial at the onset and continued to be critical throughout decades of development. The United Kingdom built the first supercomputer but kept it locked in a secret facility and classified the research; leadership in computing went elsewhere.

Mozilla Foundation's own history illustrates this dynamic from the philanthropic side. When the Foundation invested in building Firefox and defending open web standards, it was not because the browser market was failing to produce products. It was because the market alone would not protect the openness of the platform. Left unchecked, proprietary interests were closing the web. That work preserved the web as a public resource and catalyzed an era of standards-based innovation that benefited every participant in the ecosystem, from startups to governments. Similarly, open source quantum software is the kind of infrastructure that benefits everyone yet is funded by no one. The leverage an actor like Mozilla Foundation brings is structural. Philanthropic capital entering at the software

layer, before the field consolidates, shapes the terms on which the entire ecosystem develops.

Quantum computing now sits at exactly this juncture. Philanthropic and public investment in open source quantum infrastructure is high-leverage precisely because the market will not fund it on its own. The returns are diffuse. They spread across an entire ecosystem rather than being captured by a single firm. This can make it a poor fit for private capital but an excellent fit for mission-driven funders who care about the health of the field as a whole.

Unitary Foundation operates in this gap, and Mozilla Foundation's support has been instrumental in sustaining that work. Founded in 2018, Unitary Foundation is a 501(c)(3) non-profit that builds, governs, and sustains open source quantum software used across academia, industry, and government. The Unitary Foundation community includes more than 5,500 developers worldwide. Our tools are used by researchers, startups, and national laboratories alike. We support Mitiq for error mitigation, Metriq for benchmarking, the Unitary Compiler Collection for quantum circuit compilation, and long-term stewardship of projects like QuTiP. Our microgrant program has supported over 150 open source quantum projects across 31 countries, engaging more than 400 contributors and maintainers, with over 50 percent of grants going to individuals from historically underrepresented groups. We count among our supporters and partners IBM, IonQ, Pasqal, Amazon, Microsoft, Xanadu, In-Q-Tel, the University of Chicago, Stanford University, and many others. Our work has been supported by the National Science Foundation, the Department of Energy, Mozilla Foundation, and Schmidt Futures. This model works. It works because open infrastructure, maintained by a trusted neutral party, is a public good that the entire ecosystem needs.

The value runs in both directions. For Mozilla Foundation, this work is also a learning investment. Extending our open source mandate into quantum computing allows us to test whether the governance and community-building models that worked for the open web translate to an emerging, highly technical field, and to develop the institutional knowledge to be a credible, long-term partner as quantum technology matures.

4. A Call to Action

We are asking three things of the leaders who will shape the quantum future.

To funders and philanthropists: Treat open source quantum infrastructure as a category of philanthropic investment, just as organizations like Mozilla Foundation and others have long treated open internet infrastructure. The software layer of quantum technology is a public good. It deserves dedicated, sustained support—not as a side project of hardware investment, but as a strategic priority in its own right. Mozilla Foundation has spent two decades demonstrating that non-profit stewardship of open technology can reshape markets and protect public interests — each time at the moment when the field's foundational layer was still contestable. The leverage is enormous: for a fraction of what a

single quantum hardware company raises in a funding round, you can sustain the shared tools and communities that make all hardware investments more productive.

To policymakers: Ensure that public quantum programs include funding for the software layer, not just hardware. The National Quantum Initiative, the NSF Tech Labs program, and related federal efforts must recognize that open source software infrastructure is as critical to quantum competitiveness as the processors themselves. The lesson of the HPC era is clear: without an open, interoperable software ecosystem, hardware breakthroughs remain siloed and difficult to translate into capability. Fund the compilers, the benchmarking platforms, the developer tools, and the communities that maintain them.

To investors: Recognize that open source ecosystems drive the market development that makes your hardware and application bets more valuable. Every startup that can prototype on open tools rather than building from scratch reaches product-market fit faster. Every researcher who can benchmark across platforms rather than being locked to one vendor generates the comparative knowledge that matures the market. Open infrastructure is not a competitor to your portfolio companies. It is the rising tide.

If you want to feed a fire, you need to create breathing space between the logs for oxygen to flow as fuel. Open source software is that breathing space for quantum technology. It draws in the talent, the creativity, and the experimentation that will determine whether quantum computing fulfills its promise or remains an expensive curiosity. We have seen this pattern before—with the internet, with Linux, with Firefox, with open source AI. We know what works.

We will all benefit if quantum technology grows with this same openness: scaling responsibly, remaining accessible, and shaped to advance human flourishing through the fundamental rules of nature.

¹ CSIS Commission on U.S. Quantum Leadership.

<https://www.csis.org/analysis/csis-commission-us-quantum-leadership>

² Hoffmann, M., Nagle, F., & Zhou, Y. (2024). The value of open source software. Harvard Business School Strategy Unit Working Paper, (24-038).

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