Ready-to-run
Quantum Software

# QCI and Qatalyst in the Quantum Ecosystem

# Who is QCI?

Quantum Computing Inc (QCI), is a cloud-based quantum software vendor, offering ready-to-run software for complex optimization computations. The company's flagship software solution, Qatalyst, is the industry's only quantum application accelerator, empowering today's Subject Matter Experts (SMEs) to immediately leverage the power of quantum techniques for faster, better and more diverse solutions, with no need for quantum expertise or training.

QCI was founded in 2018 by leaders in supercomputing, mathematics, and massively parallel programming to solve the enormous challenges with quantum computing software development. While much of the market focuses on the Quantum Processing Unit (QPU) hardware, QCI's experts realized that the traditional SDK approach to quantum software doesn't work for non-quantum experts, given the dramatically new programming paradigm.

QCI's goals are simple.

- Deliver production-ready software that de-risks the shift to quantum computing Empower current SMEs and programmers to access the power of quantum with no quantum expertise.
- Eliminate the vendor lock-in created by low level coding to individual Quantum Processing Units (QPUs). Users can freely select the best QPU for their specific problem with no low-level coding or programming changes.
- Deliver the best performance results (speed, quality and diversity) at the lowest cost for our users.
- Deliver software and the required hardware in the cloud to make it simple and cost effective for organizations to begin to leverage quantum power.

The result is Qatalyst, the industry's only Quantum Application Accelerator. Today, Qatalyst is focused on solving real-world problems including: logistics optimization, cyber security, drug discovery, and more. The initial focus is on complex optimization problems, such as supply chain, logistics, and, cyber security.

Qatalyst's accuracy and performance have been proven against a popular industry alternative, as seen in this report from Los Alamos Laboratories:

"The QAE + Qatalyst QUBO solver combination substantially outperforms the QAE + Ocean qbsolv in terms of accuracy." Sampling electronic structure QUBOs with Ocean and Qatalyst solvers†

The company is actively working with quantum computing leaders in both hardware and software. QCI uses AWS Braket to connect to quantum computers including Rigetti, D-Wave and IonQ, to run applications, right now. The same problem can be submitted to any of these QPU or CPUs with no need for programming changes. This empowers users to determine which quantum computer (or QPU) will provide the best answers to their complex problem.



https://arxiv.org/abs/2102.01225†

QCI management believes that the development of real-world use cases, not just science projects, is critical to the forward momentum of quantum computing as a practical reality. To that end, QCI has created an internally funded program called QikStart which provides access to Qatalyst and cloud-based resources, experts, and funding to explore and push the boundaries of quantum computing for delivering practical business results, right now. QCI's Chief Technology Officer, Mike Booth, is leading the QikStart Program. Booth's deep experience and understanding of how quantum computing can add value to critical business solutions is a significant advantage to companies interested in participating in the program.

# What is Qatalyst?

## Six simple API calls to access limitless performance and power

QCI's innovative Qatalyst application accelerator bridges the power of quantum to enhance classical computing performance and quality of results. SMEs and programmers can solve even more challenging real-world computational problems with no complex programming, no quantum expertise.

Qatalyst speeds an organization's time to quantum power by masking the complexity of quantum programming via the Q API, a powerful six call API that users can learn in a day. Instead of spending months or years developing new applications and workflows requiring complex and extremely low-level coding, users, workflows or applications can immediately submit a problem to Qatalyst, using the same familiar constructs they use right now and simple Q API calls.

Quantum hardware demands tedious, low-level coding that's specific to each vendor, as well as updates for every hardware expansion or update. That's a lot of cost and hassle. Not to mention vendor lock-in. Qatalyst shields you from this complexity. You can access a variety of popular QPUs using the same API calls and problems. No low-level coding, no re-programming, no vendor lock-in.

The positive impact for the client is significant, as can be seen in the comparison below.

## Comparison: Time-to-Business-Results

SDK Toolkit Time-to-results: 7-12 months


**Qatalyst Time-to-results: 1 week or less**

Since quantum calls for such dramatic new skills and knowledge, the time-to-expertise will be significant, unless organizations can locate and hire these scarce resources. Even then, these scarce experts demand significant investments.

For a toolkit approach, this time-to-results model assumes:

- Learn basics of quantum. A highly skilled PhD or programmer can learn enough to create basic quantum problems and simple workflows in a 3-month training period, then learn more over time as they tune and optimize their first workflows and problems to obtain better solutions. NOTE: cost of training/courses is not included in the model.

- Quantum-optimize the problem, create quantum engines, create workflow. After the 3+ months of training, the PhD or programmer should be able to create a problem and workflow in approximately one month. That workflow is then processed across a single quantum computer. To process across multiple quantum machines will require the programmer/PhD to write different workflows (circuits) for the different quantum machines. Also, programmers must work with mathematicians and physicists to create a quantum optimization engine to solve the problem. The month defined in this model is not enough time to create that engine, so it assumes that the toolkits will eventually offer optimization engines, or a third-party software will be used.

- Tune and continue to optimize to get quality results. After the first workflow is submitted and delivers results, the PhD/programmer usually spends 3-6 months tuning and learning about how to best optimize the problem and the workflow to deliver the best results. For example, the iteration required for quantum processing is a highly technical mathematical process that will need to be tuned and optimized across multiple shots.

One point to note. The quantum experts at QCI estimate that it took them years to learn what they needed to know to even attempt to a) properly apply or create algorithms that effectively map problems to quantum-optimized QUBOs, b) write the workflows/ circuits and necessary deep level programs to manage the quantum qubits, c) create quantum algorithms to process the problems and d) define and create the mathematical iterations required to deliver the best possible results.

Qatalyst's approach in this model assumes:

- 1 day maximum for an SME or programmer to learn the simple calls to the Qatalyst API

- 2-3 days for the SME to create a new problem, then appropriately associate the new problem and data with a current workflow or app

- 1 day for the SME to analyze the results and tune for any specific changes

As you can see, Qatalyst's simplicity and familiarity for SMEs, as well as the API, dramatically accelerate the time-to-results for quantum computing problems. That means your teams focus on improving your business and its bottom line, not wrangling with complex new technologies.

# Qatalyst Software in Action


Qatalyst software includes the following:

**The Q API** gives organizations access the state-of-the-art capabilities of Qatalyst through six simple calls. No new programming, no new workflows. Simply add the Q API call to your current workflow or application and begin your complex computations. Qatalyst does the rest.

The Q API features six simple API calls to access limitless performance and power.

You get seamless and diverse QPU and CPU access with the same exact problem. You don't have to define complex mathematical formulas or algorithms, circuits, gates and more to run your problem. SMEs use familiar constructs to create problems, them submit those problems using whatever call(s) are needed. You can easily transform current workflows and applications by adding the appropriate API call(s).

**Q Graph** is a powerful transformation engine that empowers SMEs to submit and analyze graph models as part of their complex optimizations. Graph models offer a powerful way to create problem sets and analyze results. The challenge? The complexity of most complex computations leads to such large graphs that it has been nearly impossible to use graph modeling in many computational areas.

QGraph changes that, empowering SMEs, programmers or current workflows to work with familiar graph models. QGraph accepts familiar graph models and functions including Clique Cover, Community Detection and Partitioning. It automatically transforms the graph model into a constrained optimization problem and then submits it to the Qatalyst Core for processing. When results are returned, QGraph transforms them into a graph model to deliver to the SME or application.

**The Qatalyst Core** provides sophisticated mathematics, quantum transformation and iterative processing to find the most excellent answers across classic and quantum computers.

The Core features a variety of complex mathematical modules to prepare, optimize, iterate and solve complex computations. For example:

- **LaGrange multipliers.** Advanced mathematics compress and simplify the problem prior to constraint optimization. The Core applies these advanced mathematical techniques, based on the type of problem and processing required. Once requests are submitted for processing, results are iteratively optimized until the best results are identified.

- **Sampling Quadratic Unconstrained Binary Optimization Algorithm (QUBO).** The Core automatically maps real-world problems into physics-based problems in a multidimensional space that quantum computers require for processing. QUBOs represent the quantum problem, which is a result of the transformation of binary requests into the multi-dimensional space of quantum physics. QUBOs are the native format used by annealing quantum computers, such as D-Wave.

- **Sampling QUBOs on gate-model QCs with the Quantum Approximate Optimization Algorithm (QAOA).** The Core automatically applies the QAOA algorithm to QUBOs to optimize problems for submission to gate model quantum computers, such as Rigetti and IBM.

- **QPU Independence.** Qatalyst controls both the physical and logical qubits, maintaining strict chains of computation. These controls apply to three different computing paradigms; gate models, annealers and classic computers. As a result, Qatalyst eliminates the hardware limitations often caused by physical to logical mapping of qubits. It also eliminates the need for low-level hardware programming and reprogramming, accelerating time to results while dramatically reducing overall application development and lifecycle costs. This also eliminates the need to choose a QPU for specific low-level coding, avoiding vendor lock-in. Today, Qatalyst seamlessly supports QPUs from Rigetti, ION-Q and D-Wave, with more vendors in process. The same exact problem runs across all of these platforms, or a classic system, with no programming changes.

- **Qontrol.** includes microservices that manage all requests, provide status, alerts and more. The Qontrol portal gives admins simple management tools for user and Qatalyst administration. Users access Qatalyst through the portal to submit and track their requests.

For end-to-end request management, Qontrol delivers:

- CPU/QPU resource check and configuration to assure that resources are available and properly configured for the specific problem request.

- CPU/QPU scheduling and submission. Qontrol schedules the request for a future time, or submits it immediately, as appropriate for each request and resource availability.

- Visual progress tracking and alerts let you see the progress of your request as its processing. You're also alerted if there are any issues you need to resolve.

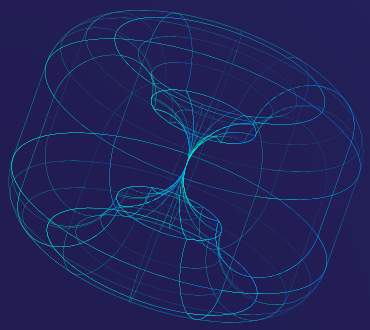
- Analytics Data for admins and users that is easy to import into current analysis tools such as Excel and Tableau.

**The Qontrol Portal** provides admins with everything you need to create and manage user accounts and permissions, control request flows and resource utilization, monitor costs and report on budgets, track request progress, quickly respond to alerts to minimize disruptions, see input, results, and performance info for recent requests, abort unintended or malformed requests.

Users get visibility into their individual requests, as well as requests from workflows and applications they manage. Users can track progress of their requests, receive alerts if there are any issues, see results and abort unintended or malformed requests.

$$\hat{H} = \sum_{n=1}^{N} \frac{\hat{p}_n^2}{2m_n} + V(x_1, x_2, \ldots x_N)$$

$$\frac{-\hbar^2}{2m} \frac{\partial^2 \Psi(x,t)}{\partial x2} + U(x)\,\Psi(x,t) = it \frac{\partial \Psi(x,t)}{\partial t}$$



## The Bottom Line

Qatalyst is a highly sophisticated, quantum application accelerator for complex computations. It is ready-to-run, in the cloud.

- Its advanced optimization solves complex mathematical computations faster, while delivering a diversity of high-quality results. Users no longer have to bet their decisions on a a single computational result.
- By eliminating the need for quantum expertise and complex programming, Qatalyst accelerates time to business results. It uses familiar SME constructs. Simply add a Q API call to current workflows and applications, and they, too, access Qatalyst power.
- Since Qatalyst dynamically controls qubits, there's no need for low-level, hardware specific coding, which means no vendor lock-in. Choose one QPU for your computation today, choose another tomorrow. Same problem, same request, no recoding.

Qatalyst seamlessly blends classic and quantum computing to provide better solutions on classic systems today, with a seamless evolution to solve those same problems on quantum when hardware scales to meet production needs.

Faster time-to-results, faster time-to-quantum, no programming required.

**Quantum Computing Inc. | (703) 436-2161 | quantumcomputinginc.com**