iCV TAnK
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& Knowledgebase

# Global Quantum Computing Cloud Platform

## Research report

July.2023

# Preface

Quantum computing, with its extraordinary computational abilities, is widely regarded by both the academic and industrial communities as a key to unlocking the potential for enhanced computing power. In recent years, quantum computing cloud platforms have played an increasingly vital role as significant bridges in realizing the commercialization and popularization of quantum computing. These platforms not only provide users with convenient access to quantum computing resources but also facilitate the development and optimization of quantum algorithms, presenting both opportunities and challenges for the academic and industrial spheres.

This report is divided into five chapters. The first chapter provides an overview of quantum computing cloud platforms and explores their advantages in scientific research and commercial domains. The second chapter focuses on the development and features of quantum computing cloud platforms in the first half of 2023, detailing the latest progress made in the industry during this period. The third chapter primarily investigates the global leading companies and products in the development of quantum computing cloud platforms, with case studies including IBM Q Experience, Amazon Braket, Microsoft Azure, and QuantumCTek, and outlines their cloud platform upgrade and developmental trajectories. The fourth chapter concentrates on testing and evaluation, with special attention to processor types and performance, user interface usability, pricing structures, technical and community support, scalability, and future developments. The fifth chapter offers a summary and outlook on the global quantum computing cloud platform industry, discussing future trends, including the emergence of more quantum computing service providers, realization of quantum advantage, development of hybrid quantum and classical computing models, increased cross-disciplinary collaboration, growth in quantum computing education and training, and the introduction of more robust and user-friendly quantum programming tools.

Through this report, we aim to provide readers with a comprehensive understanding, enabling them to better grasp the importance of quantum computing cloud platforms and their potential impact on the future of computing. We believe that this report will offer valuable insights for scientists, engineers, and entrepreneurs and contribute to the advancement of quantum computing cloud platform development.

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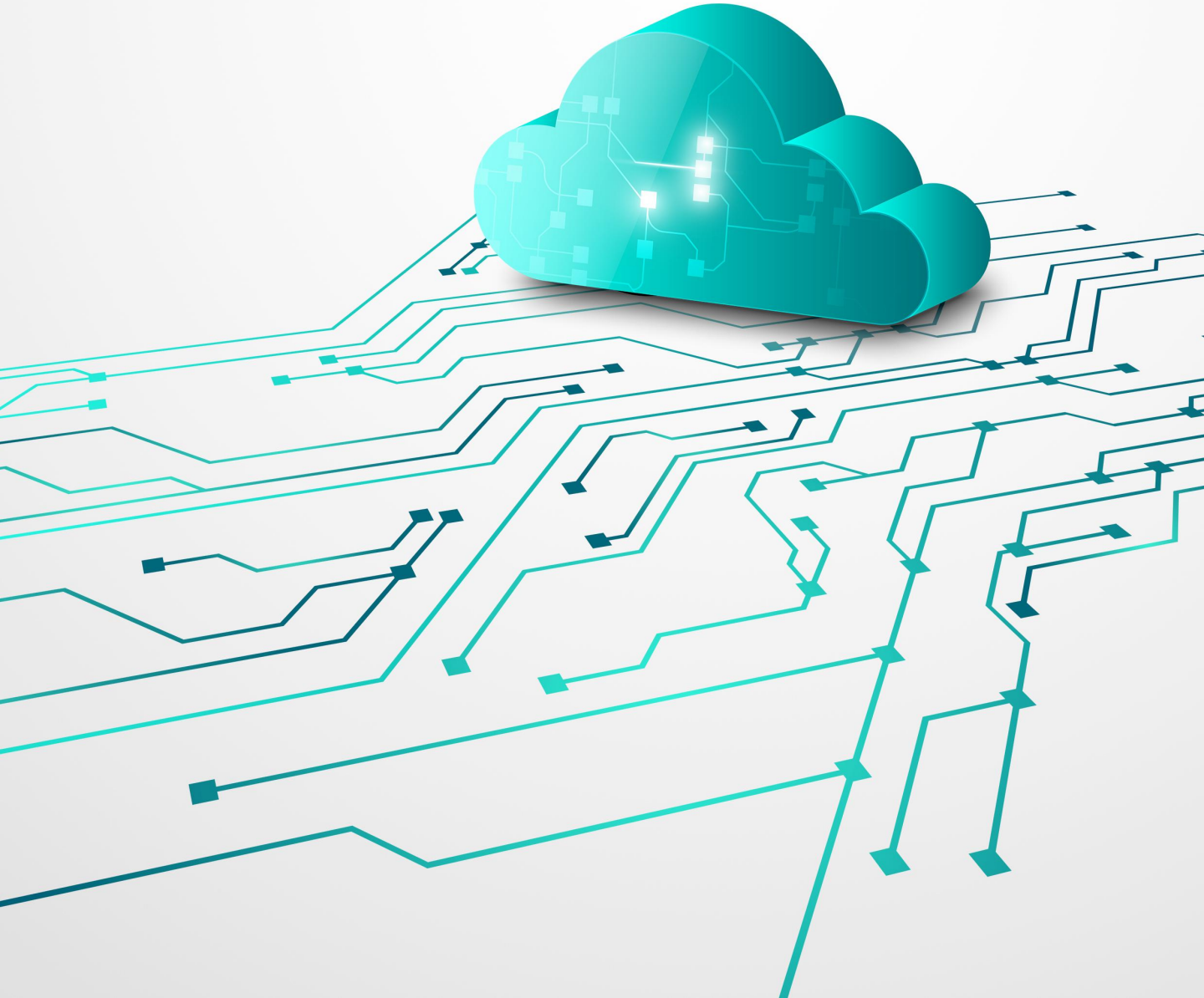
# Introduction



# Quantum Computing Cloud Platform Introduction

Due to the demanding operational requirements and high acquisition and maintenance costs of quantum computers, it has become challenging for ordinary users to afford purchasing and utilizing a quantum computer. However, the emergence of quantum cloud platforms addresses this issue. With quantum cloud platforms, users can upload their developed quantum programs to the backend quantum computer or quantum virtual machines for computational processing and obtain results. This solution allows users to access quantum computing capabilities without the need for expensive hardware and maintenance, making it more accessible and cost-effective for a broader audience.

Figure: Workflow chart of quantum computing cloud platform

The quantum computing cloud platform serves as the intermediary bridge between users and the quantum computing system. When a classical computing device initiates a computation task request to the quantum system, the quantum cloud platform facilitates the transmission of this request. Subsequently, after the quantum system completes the computation task, the results are conveyed back to the user in classical information format through the quantum cloud platform. Throughout this process, the quantum cloud platform plays a crucial role as the facilitating intermediary, enabling seamless interaction and communication between users and the quantum computing system.

# Comparison of Quantum Computing Cloud Platform

Based on the differences in the regions of operation, we conducted an analysis of quantum computing cloud platforms for eight companies in North America, five companies in Europe, and six companies in Asia. The analysis encompassed various dimensions, including the release date of the platforms, hardware technology providers, backend hardware accessibility, and the number of accessible qubits (qubits).

Figure: Comparison of each quantum computing cloud platforms

| Platform | Release Year | Country | Technology Provider | Physics Hardware | No. of Qubits |
|---|---|---|---|---|---|
| North America | | | | | |
| IBM Q Experience | | | | | |
| Google Cloud | | | | | |
| Rigetti QCS | | | | | |
| Amazon Braket | | | | | |
| Microsoft Azure Quantum | | | | | |
| D-Wave Leap | | | | | |
| Strangeworks QC™ | | | | | |
| Xanadu Cloud | | | | | |

Source: Company's official website, ICV TAnK

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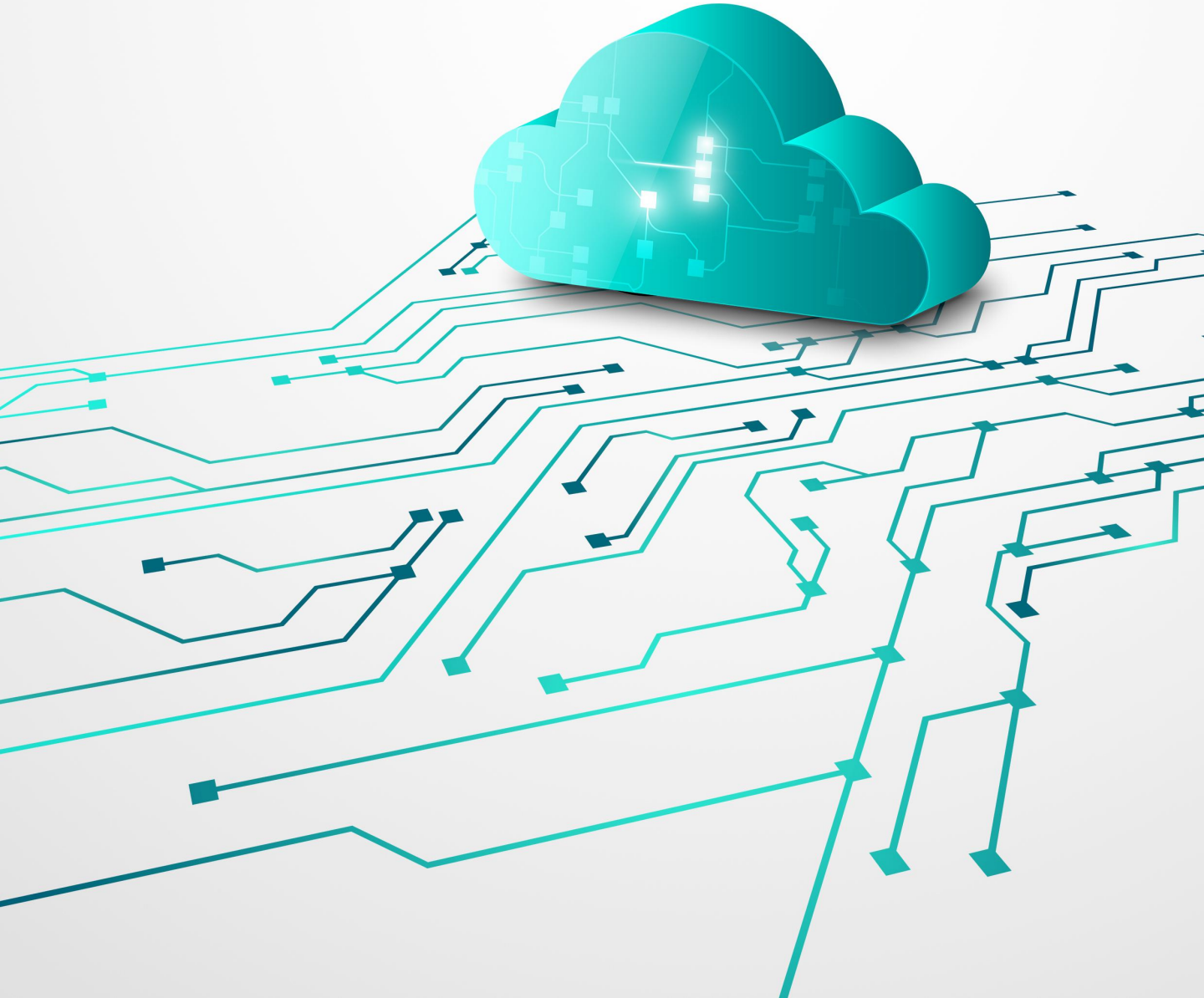
# Progress



# Progress of Quantum Computing Cloud Platforms

In the first half of 2023, several companies made significant advancements in the development of quantum computing cloud platforms. In January, IBM announced the launch of their 433-qubit processor, Osprey, on their quantum cloud platform, which also provided access to a 5000-qubit quantum simulator. In May, the Beijing Institute of Quantum Information Science introduced the Quafu Quantum Computing Cloud Platform, offering 136 interconnected and independently controllable qubits. Additionally, in May, QuantumCTek unveiled its quantum computing cloud platform, granting users access to 176 qubits (66 qubits and 110 coupling bits). In June, Strangework announced the integration of IBM's 127-qubit Eagle processor into their cloud platform, offering a pay-as-you-go system for quantum services.

Figure: 1H 2023 major progress in quantum computing platforms

| Institution | Time |
|---|---|
| Microsoft Azure | Mar 2023 |
| IBM Quantum | May 2023 |
| 北京量子信息科学研究院 Beijing Academy of Quantum Information Sciences | May 2023 |
| 国盾量子 QuantumCTek | May 2023 |
| STRANGE WORKS | Apr 2023 |
| | Jun 2023 |

Source: Company's official website, ICV TAnK

# Commercial Use Cases for QC Cloud Platform

Currently, quantum computing cloud platforms have demonstrated practical applications in various fields such as materials science, finance, manufacturing, healthcare, cybersecurity, artificial intelligence, education, entertainment, agriculture, and more.

Figure: Commercial use cases for each quantum computing cloud platform

| Industry | Company | Cloud Platform | Use Cases |
|---|---|---|---|
| Material sciences | Bosch | IBM Q Experience | |
| Finance | JPMorgan Chase | Amazon Braket | |
| Manufacturing | Volkswagen | Google Quantum AI | |
| Healthcare | Biogen | Microsoft Azure Quantum | |
| Cybersecurity | Post-Quantum | AWS Marketplace | |
| Artificialintelligence | Xanadu AI | Xanadu Quantum Cloud | |
| Education | MIT | IBM Q Experience | |
| Entertainment | Netflix | Google Quantum AI | |
| Agriculture | Bayer Corp Science | Microsoft Azure Quantum | |

Source: Company's official website, ICV TAnK

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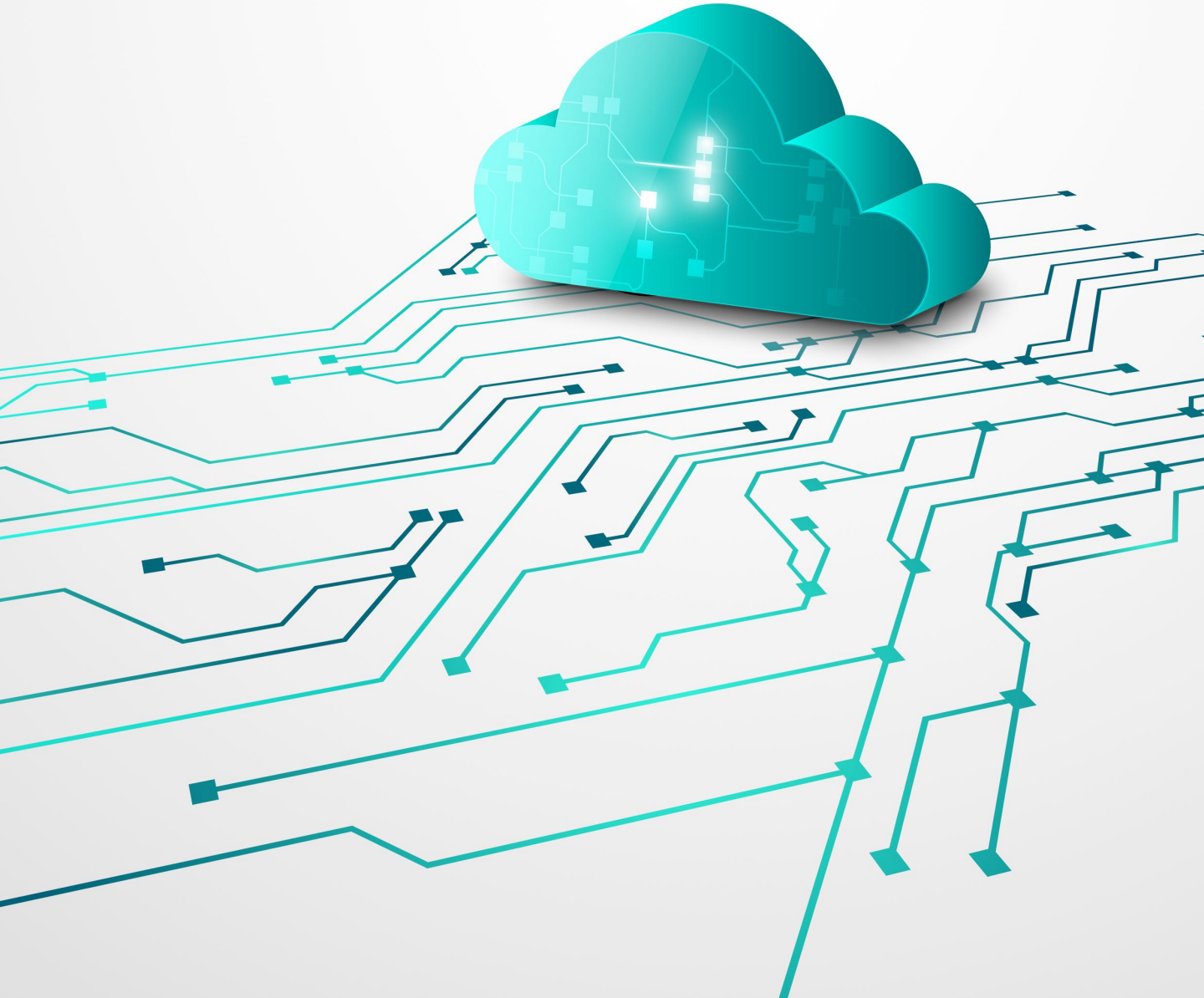
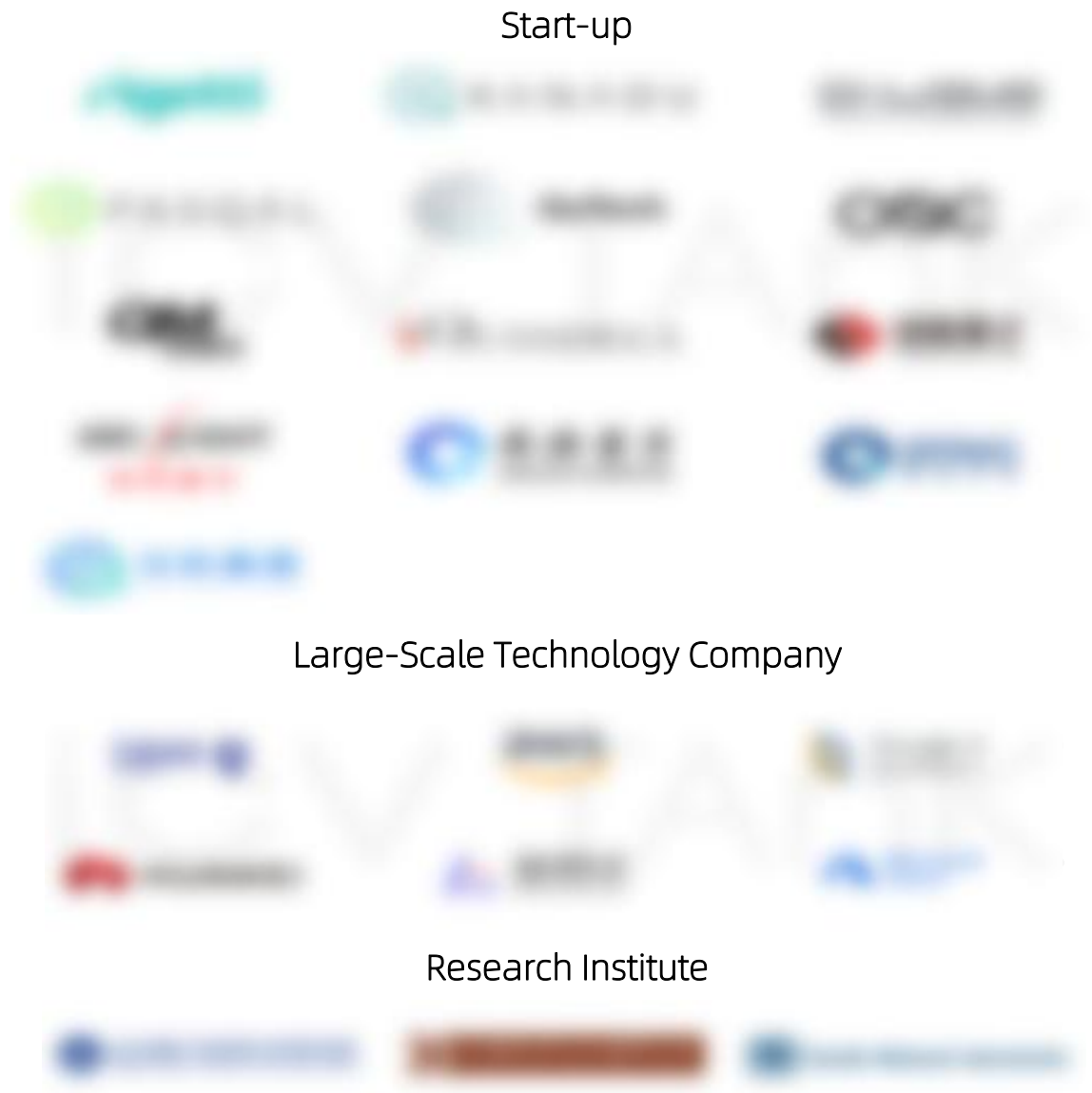
# Participant



# Global Distribution of QC Cloud Platforms

Currently, there are approximately 21 companies worldwide that have opened their quantum computing cloud platforms, including IBM's IBM Quantum Experience, Google Cloud, Microsoft's Azure Quantum, Amazon AWS's Braket, D-Wave's Leap, Rigetti's Quantum Cloud Service, Xanadu's Xanadu, Strangeworks' Strawberry Fields, Origin Quantum's cloud platform, QuantumCTek's quantum computing cloud platform, Huawei's HiQ, and more. These cloud platforms exhibit diversity in terms of backend hardware, simulators, and pricing structures, reflecting a dynamic trend in the commercialization of the quantum computing industry.

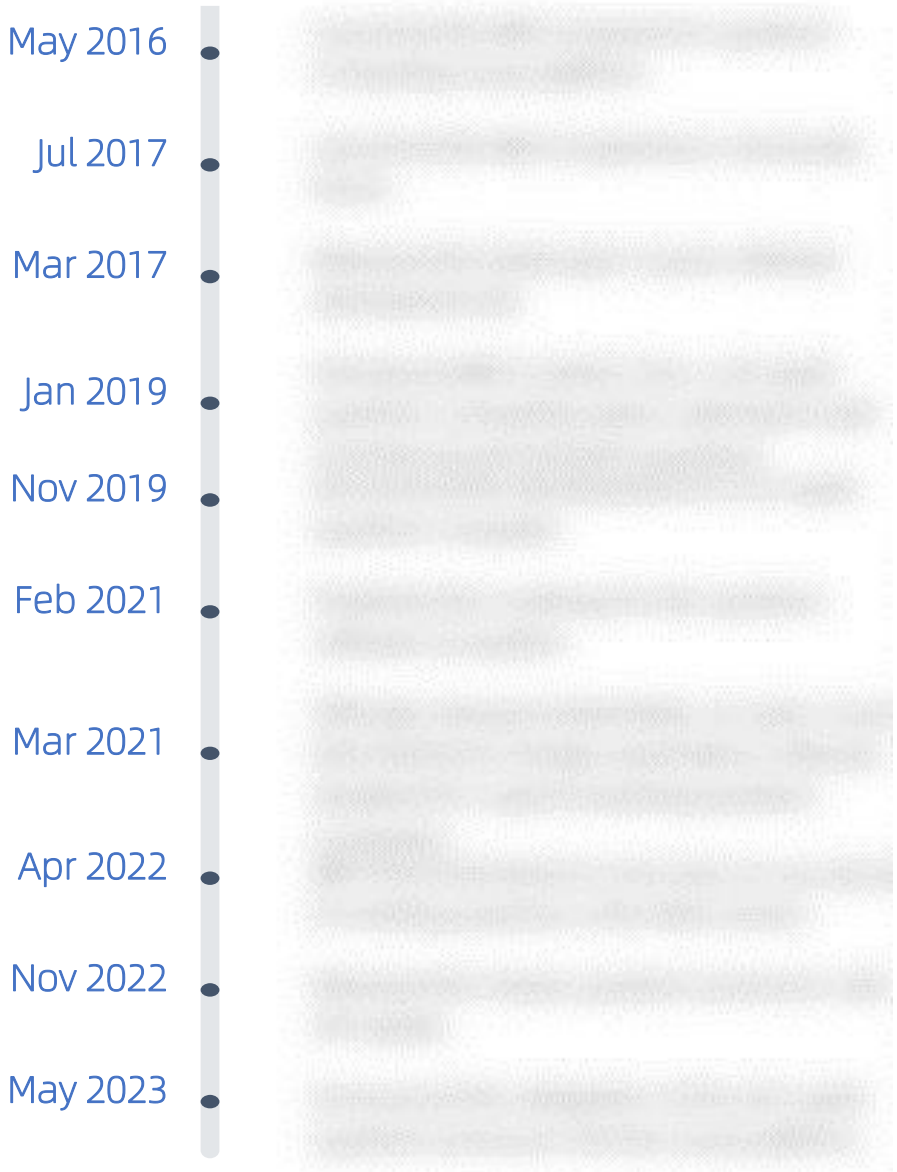
Figure: The main institutions of the global quantum computing cloud platform




Source: ICV TAnK

# IBM Q Experience and Development Timeline

In May 2016, IBM launched the quantum computing cloud platform known as IBM Quantum Experience, allowing users to run algorithms and experiments on IBM's quantum processors. This marked the beginning of quantum computing cloud services worldwide. In November 2022, IBM unveiled its Osprey chip, boasting 433 qubits, making it the world's publicly available superconducting quantum system with the highest qubit count. In June 2023, the Osprey chip was officially launched on IBM's cloud, made available for external testing, primarily targeting members of the IBM Quantum Network. However, the IBM quantum computing cloud platform restricts access from IP addresses located in China.



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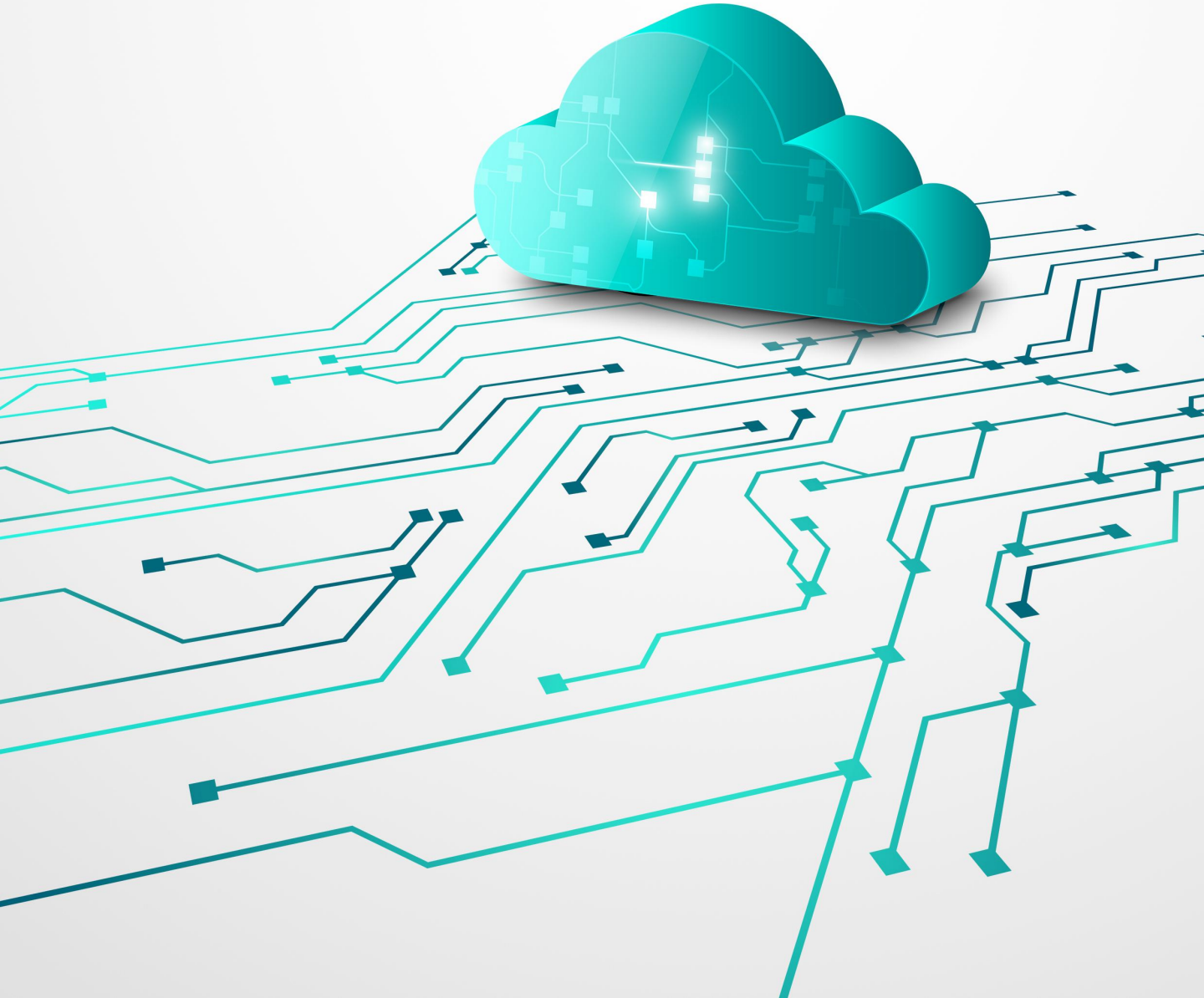
# Test & Evaluation



# Backend Hardware Performance

## IBM Q Experience

IBM Quantum systems are built using world-leading quantum processors, cryogenic components, control electronics, and classical computing technology.

Figure: Hardware parameters of each IBM system on IBM Q Experience backend

| Name of processor | No. of Qubits | Median ECR Error | Median SX Error | Median Readout Error | Median T1 | Median T2 |
|---|---|---|---|---|---|---|
| ibm_seattle | | | | | | |
| ibm_sherbrooke | | | | | | |
| ibm_kyiv | | | | | | |
| ibm_brisbane | | | | | | |
| ibm_nazca | | | | | | |
| ibm_cusco | | | | | | |
| ibm_ithaca | | | | | | |
| ibm_algiers | | | | | | |
| ibmq_kolkata | | | | | | |
| ibmq_mumbai | | | | | | |
| ibm_cairo | | | | | | |
| ibm_auckland | | | | | | |
| ibm_hanoi | | | | | | |
| ibm_peekskill | | | | | | |
| ibmq_guadalupe | | | | | | |
| ibm_perth | | | | | | |

Source: Company's official website, ICV TAnK

## QuantumCTek QC Cloud Platform

QuantumCTek 176-qubit cloud platform is a quantum computing service that connects to a superconducting quantum computer, which uses the same quantum computing chip as "Zu Chongzhi", with 176 controllable qubits. This is the superconducting quantum computer with the most qubits on the Chinese cloud platform so far .

Figure: Hardware parameters of QuantumCTek on QuantumCTek QC Cloud Platform backend

| Task | \|0> readout fidelity | \|1> readout fidelity | Graph Result |
|---|---|---|---|
| Qubits Flip(X) | 0.95 | 0.95 | \|0> : 0.4892<br>\|1> : 0.5108 |

| Qubit No. | Readout Error (%) | Qubit No. | Readout Error (%) | Qubit No. | Readout Error (%) | Qubit No. | Readout Error (%) |
|---|---|---|---|---|---|---|---|
| Q0 | | Q15 | | Q33 | | Q49 | |
| Q2 | | Q16 | | Q34 | | Q50 | |
| Q3 | | Q18 | | Q35 | | Q51 | |
| Q4 | | Q19 | | Q37 | | Q52 | |
| Q5 | | Q20 | | Q38 | | Q54 | |
| Q6 | | Q22 | | Q39 | | Q55 | |
| Q7 | | Q23 | | Q40 | | Q56 | |
| Q8 | | Q24 | | Q42 | | Q57 | |
| Q9 | | Q25 | | Q43 | | Q58 | |
| Q10 | | Q27 | | Q44 | | Q62 | |
| Q11 | | Q28 | | Q45 | | Q63 | |
| Q12 | | Q30 | | Q46 | | Q64 | |
| Q13 | | Q31 | | Q47 | | | |
| Q14 | | Q32 | | Q48 | | | |

Source: Company's official website, ICV TAnK

# Interface Ease-of-Use

User interface and ease of use are an important indicator of how user-friendly a quantum computing cloud platform is. User interface includes graphical interface and command line interface, and ease of use includes programming language, framework, tools, documentation and other aspects. The higher the user interface and ease of use, the lower the threshold and cost for users to use the platform.

Figure: Comparison of interface ease-of-use between different quantum cloud platforms

| Platform | Programming Languages | Development Tools | Tutorials |
|---|---|---|---|
| IBM Q Experience | | | |
| Azure Quantum | | | |
| Amazon Braket | | | |
| QuantumCTek QC Cloud Platform | | | |

Source: Company's official website, ICV TAnK

QuantumCTek QC Cloud Platform provides a graphical interface that allows users to register for an account, request a trial, create a project, write code, select a device, and view results via a web browser.

The QuantumCTek QC Cloud Platform supports the Python language and provides a software development kit called Gdtk, which contains the basic components for building and running quantum algorithms.

The QuantumCTek QC Cloud Platform also provides documentation, tutorials and case studies to help users learn and use quantum services. However, the user language is currently limited to Chinese.

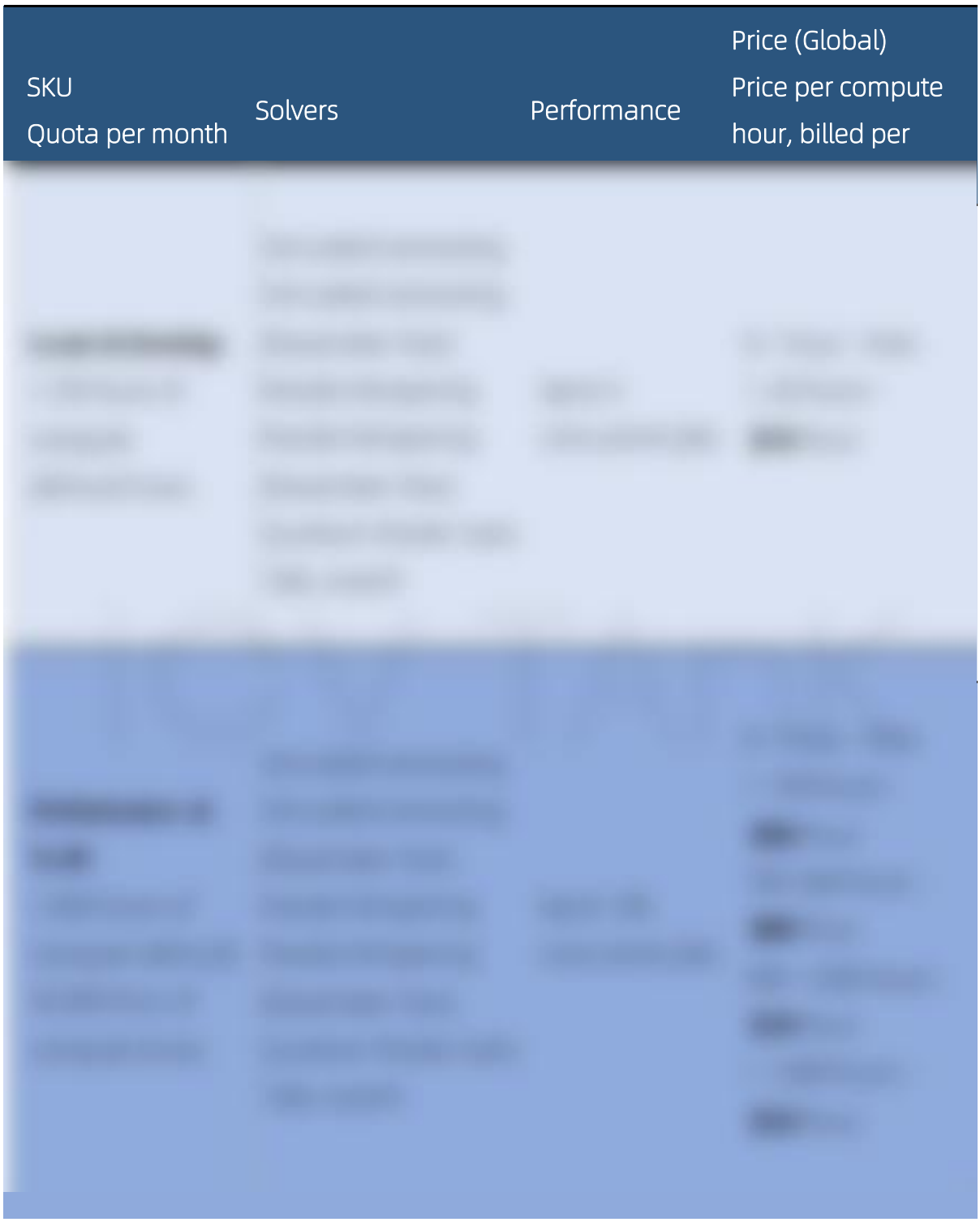
Figure: Example of quantum cloud platform operator interface for QuantumCTek QC Cloud Platform

Source: Company's official website, ICV TAnK

# Price situation

## Microsoft Azure

Figure: Quantum cloud platform pricing for Microsoft Azure Quantum



| SKU<br>Quota per month | Solvers | Performance | Price (Global)<br>Price per compute hour, billed per |
|---|---|---|---|

Source: Company's official website, ICV TAnK

## Amazon Braket

AWS's free package provides users with one hour of free quantum circuit simulation time per month, which can be used on any combination of SV1, DM1, TN1, or the three managed quantum circuit simulators.

In contrast to IBM's focus on hardware development, Amazon leans more towards a Q-PaaS (Quantum Platform-as-a-Service) model where they connect to other companies' hardware resources rather than developing their own. Amazon Braket SDK includes a free local simulator. Additionally, there are three fully managed on-demand simulators:

Figure: Quantum cloud platform pricing for Amazon Braket (simulator)

| Simulator | Rate per minute |
|---|---|
| DM1 | $ 0.075 |
| SV1 | $ 0.075 |
| TN1 | $ 0.275 |

Source: Company's official website, ICV TAnK

There are two pricing components when using a quantum computer, or quantum processing unit (QPU), on Amazon Braket: a per-shot fee and a per-task fee.

Figure: Quantum cloud platform pricing for Amazon Braket (real processor)

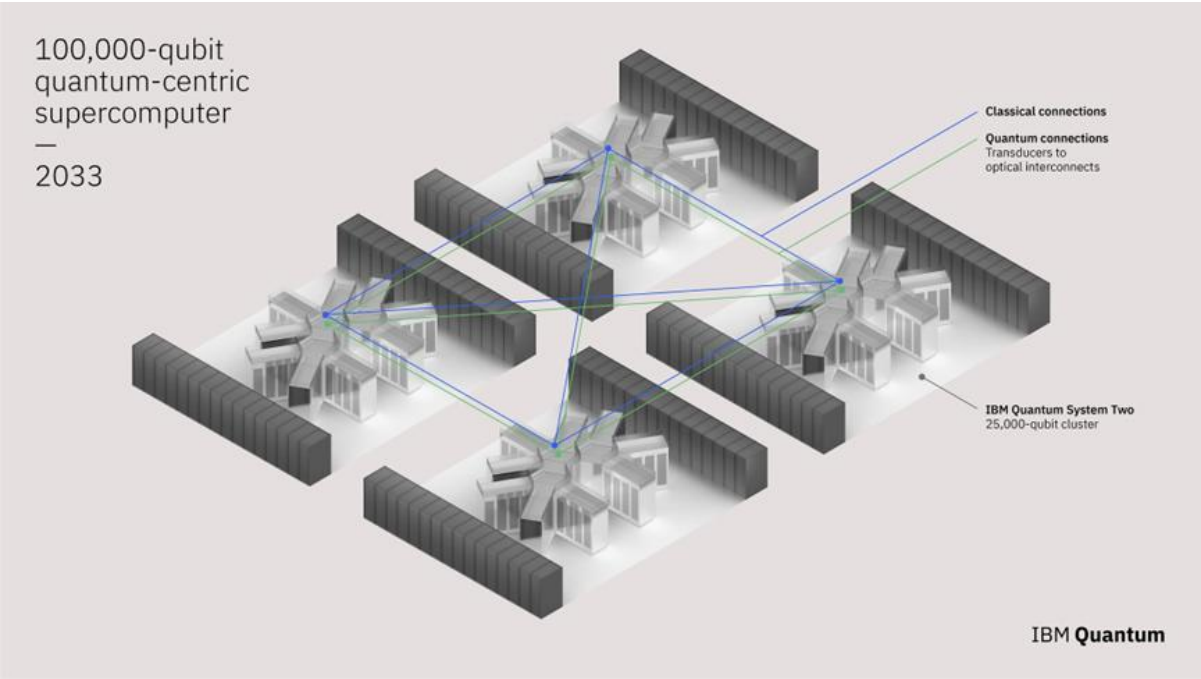
| Hardware Provider | QPU family | Per-task price | Per-shot price |
|---|---|---|---|
| IonQ | Harmony | | |
| IonQ | Aria | | |
| OQC | Lucy | | |
| Quera | Aquila | | |
| Rigetti | Aspen-M | | |
| Xanadu | Borealis | | |

Source: Company's official website, ICV TAnK

# Scalability and Future Development

- IBM announced a new quantum computing roadmap in the first half of 2023, demonstrating its planned goals for the scalability and error-correction performance of quantum computing processors. in

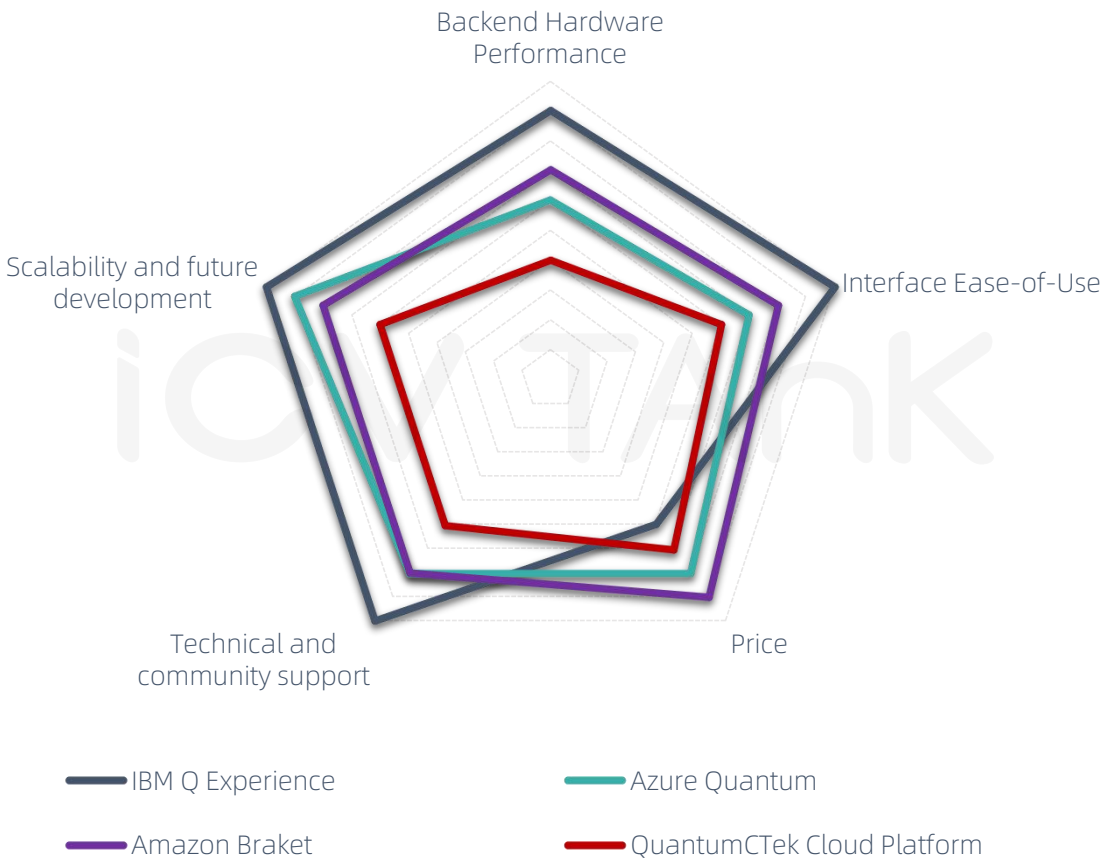
Figure: Cloud platform backend hardware provider IBM's scalability and future growth




Source: Company's official website

# Evaluation Summary

Figure: Comprehensive evaluation of each quantum cloud platform




Source: ICV TAnK

## Evaluation Rules

### Backend Hardware Performance

This item evaluates the type, scale, fidelity, coherence time, connectivity and other indicators of the backend hardware for quantum computers and simulators provided by the quantum computing cloud platform, reflecting the computing capability and quality of the quantum computing cloud platform. The higher the score, the better the backend hardware performance. The specific evaluation rules are as follows:

0 points: It means that no quantum computer or simulator is provided.

0.1-0.3 points: It means that the type, scale, fidelity, coherence time, connectivity and other indicators of the quantum computer or simulator provided are lower compared to similar products, such as only one type, scale less than 10-qubit, fidelity less than 90%, coherence time less than 10 microseconds, connectivity less than 2.

0.4-0.6 points: It means that the type, scale, fidelity, coherence time, connectivity and other indicators of the quantum computer or simulator provided are general, such as two types, scale between 10-qubit and 50-qubit, fidelity between 90% and 95%, coherence time between 10 microseconds and 100 microseconds , connectivity between 2 and 4.

0.7-0.9 points: It means that the type, scale, fidelity, coherence time , connectivity and other indicators of the quantum computer or simulator provided are relatively high , such as three types , scale between 50-qubit and 100-qubit , fidelity between 95% and 99% , coherence time between 100 microseconds and 1000 microseconds , connectivity between 4 and 8.

1 point: It means that the type , scale , fidelity , coherence time , connectivity and other indicators of the quantum computer or simulator provided are higher compared to similar products, such as four or more types , scale greater than 100-qubit , fidelity greater than 99% , coherence time greater than 1000 microseconds , connectivity greater than 8.

Interface Ease-of-Use

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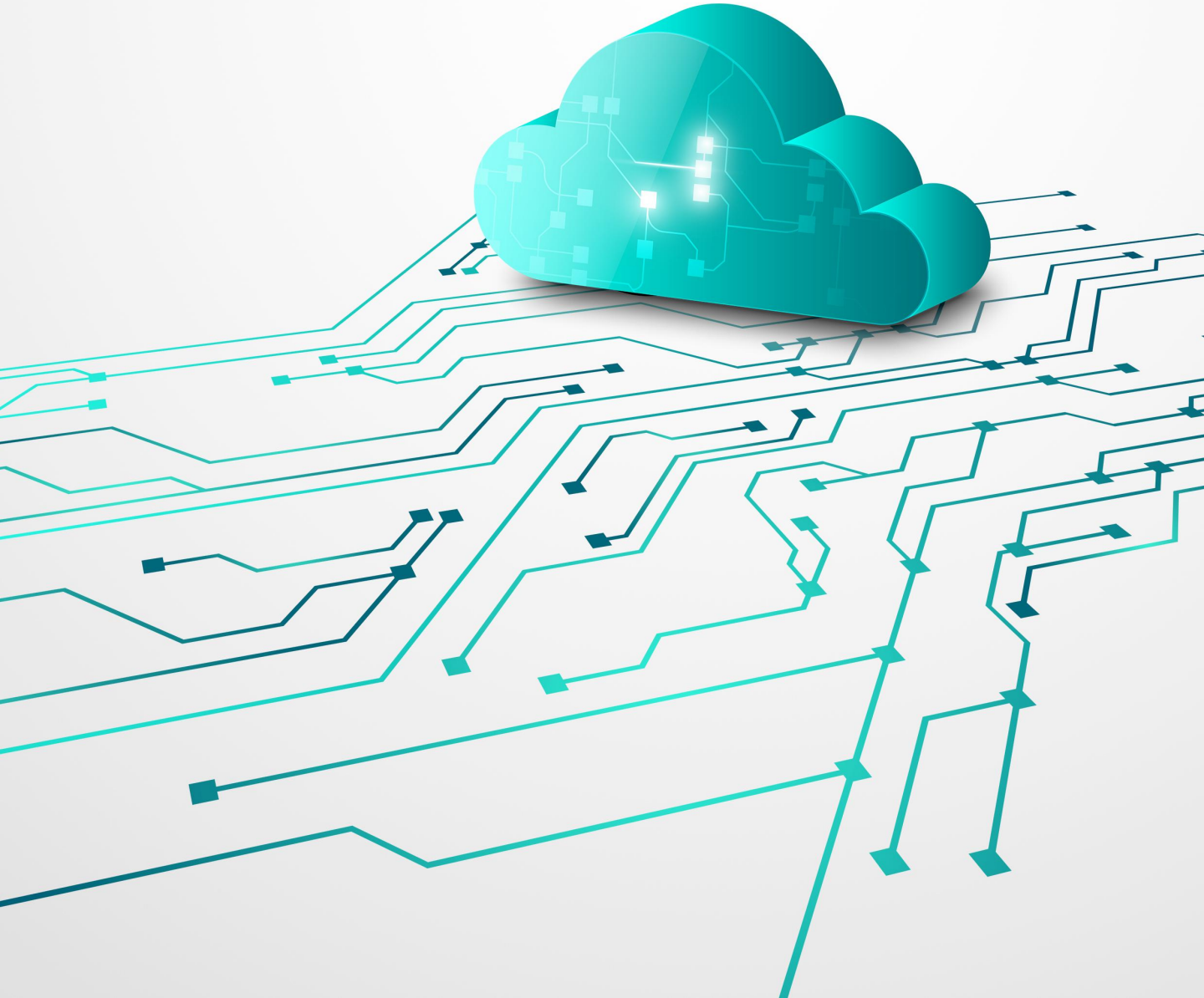
# Outlook



# Future Trends of QC Cloud Platforms

Based on the current technological development and market demand, the following are predicted future trends:

More Quantum Computing Service Providers: As quantum computing continues to advance, it's expected that more companies will enter the quantum computing cloud platform market, offering diverse quantum computing services. This influx is anticipated to bring about increased competition and fuel rapid industry growth.

Realization of Quantum Advantage: In the coming years, quantum computing may demonstrate clear advantages over classical computing in specific problem domains or applications, such as optimization, simulation, and machine learning. This could lead to a greater number of users and enterprises adopting quantum computing cloud platforms.

Development of Hybrid Quantum and Classical Computing Models: Quantum computing is unlikely to fully replace classical computing in the future; instead, it may complement it to address problems that classical computers find challenging. As a result, hybrid models that combine both classical and quantum computing are expected to be developed. Quantum computing cloud platforms will play a pivotal role in this development, as they provide the infrastructure and resources needed to explore and implement these hybrid solutions, bridging the gap between classical and quantum technologies and allowing for the seamless integration of both.

Increased Interdisciplinary Collaboration: The further advancement of quantum computing cloud platforms may require collaboration among various professionals, such as physicists, computer scientists, engineers, and others. This will likely foster interdisciplinary cooperation and innovation.

Growth in Quantum Computing Education and Training: With the growing recognition of quantum computing's importance, there might be an increase in investment in educational and training resources for learning and researching this field. This is expected to help cultivate a new generation of quantum computing experts.

# Ordering Information

Global Quantum Computing Cloud Platform Research (1H 2023 )

| | |
|---|---|
| Electronic (1-5 users) | 6,500.00 USD |
| Electronic (6-10 users) | 9,200.00 USD |
| Electronic and 1 Hardcopy (1-5 users) | 7,250.00 USD |
| Electronic and 1 Hardcopy (6-10 users) | 9,950.00 USD |

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