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Defiance ETFs

Investment Case for QTUM: Quantum Computing and Machine Learning

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Quantum Computing (QC) describes the next generation of computing innovation, which could in turn support transformative scope and capacity changes in Machine Learning (ML). QC harnesses the peculiar properties of subatomic particles at sub-Kelvin temperatures to perform certain kinds of calculations exponentially faster than any traditional computer is capable of. They are not just faster than binary digital electronic (traditional) computers, they process information in a radically different manner and therefore have the potential to explore big data in ways that have not been possible until now. Innovation in QC is directly linked to developments in ML, which relies upon machines gathering, absorbing and optimizing vast amounts of data.

Companies leading the research, development and commercialization of QC include Google, Microsoft, IBM, Intel, Honeywell, IonQ, D-Wave and Regetti Computing.

Governments, financial services companies, international retail firms and defense establishments have all joined tech giants IBM, Google and Microsoft in recognizing and investing in the potential of QC. While there is only one company currently offering to ship you a Quantum Computer for $15m, IBM have offered cloud access to their 5 and then 20 qubit QCs since 2016 (a qubit is the basic unit of quantum information—the quantum version of the classical binary bit), in order to allow researchers to work collaboratively to advance a breakthrough in this cutting-edge field. The evolution of QC and its applications have been analogized to that of the PC, whose development and full functionality were not predicted when it was first developed.[1] Near-term utilization is foreseen however, in drug discovery, the optimization of complex systems, artificial intelligence, risk management, retail, cyber security, materials science, defense, energy, and logistics.

What are Quantum Computers?

Quantum Computers (QCs) are currently incredibly large machines that are highly sensitive to electrical, magnetic and thermal "noise" - they therefore require their own room to ensure proper operational conditions. (The commercially available D-wave QC is housed in a 10 foot tall container. The image shows a non-insulated or cooled QC that would not actually function due to the conditions).

QCs exploit certain physical phenomena - superposition, entanglement, and interference - to store and manipulate information in devices called qubits. Qubits are typically unstable and perishable- they maintain their state for around 50 microseconds before errors creep in.

[1] "ITIF Technology Explainer: What Is Quantum Computing?" 20 September, 2018, https://itif.org/publications/2018/09/20/itif-technology-explainer-what-quantum-computing

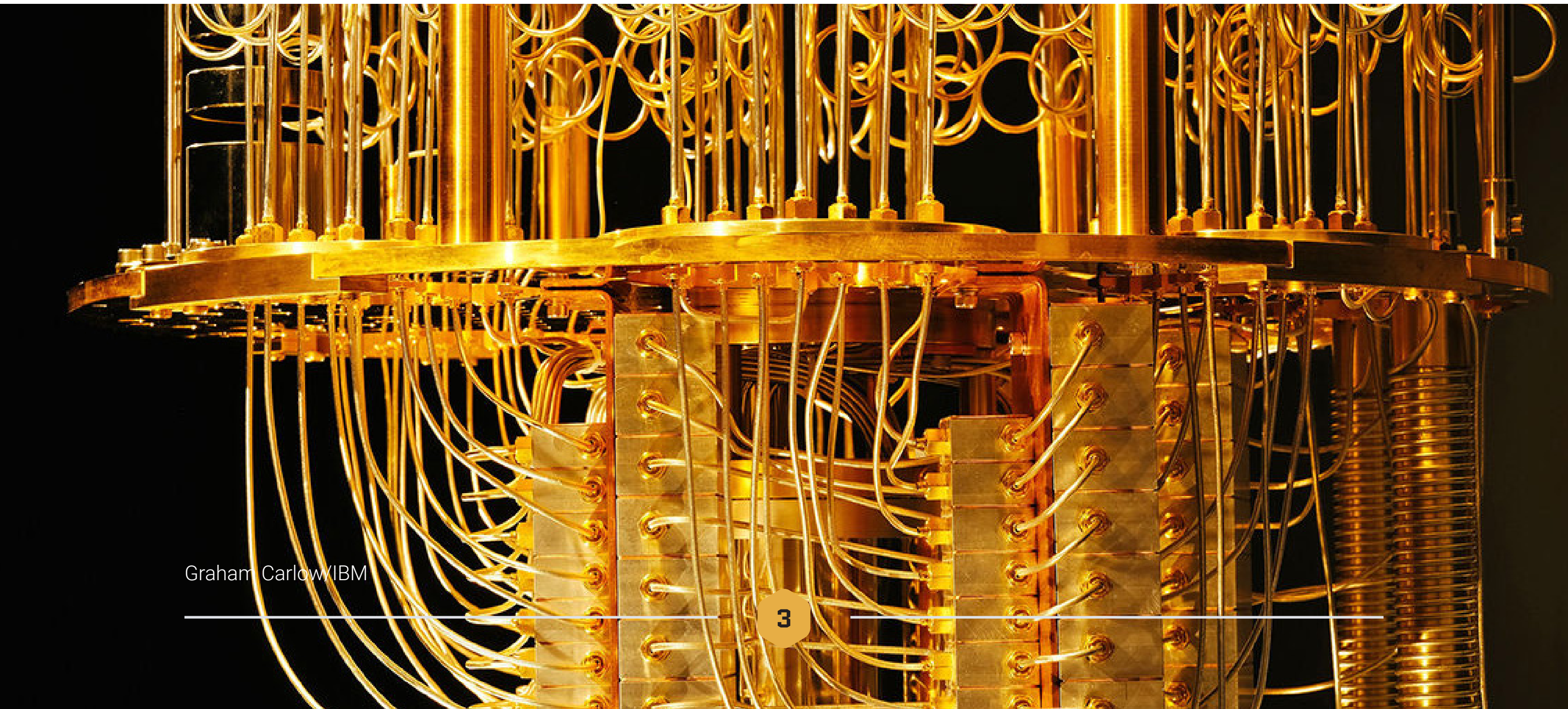
Superposition refers to the combination of states that would usually be described independently. To explain this by analogy: if you play two musical notes at once, you hear the superposition of the two notes.

Entanglement is a highly counter-intuitive quantum phenomenon describing behavior that is not classically logical or observable in the perceivable physical world. Entangled particles behave together as a system so that a change to one influences the other, even if the two particles are physically distant from each other.

Quantum interference can be understood similarly to wave interference; when two waves are in phase, their amplitudes add, and when they are out of phase, their amplitudes cancel.

Quantum Computing takes advantage of quantum mechanics rather than electrical conductivity (as in classical computers). While the latter hold information in bits (short for binary digits – these can be either 0 or 1) and perform calculations using circuits that implement Boolean algebra (the logic of true/ false, and/or); QCs exploit the behavior of subatomic particles such as electrons and photons, which can exist in multiple distinct states simultaneously (imagine 0 and 1 at the same time) and whose states can be described only probabilistically using complex numbers. QC's use linear algebra to manipulate matrices of complex numbers and unlike classical computers that must consider possibilities one at a time, they can consider all outcomes at the same time.

For example, a classical search algorithm would require 5 million attempts to find a phone number in a phone book of 10 million entries; a QC algorithm could do it in just 1,000 operations - 5,000 times faster.



Graham Carlow/IBM

In October 2019 Google officially announced that it had achieved "Quantum Supremacy," with its 54 qubit QC Sycamore apparently solving a mathematical calculation in 200 seconds that would take a supercomputer 10,000 years.[2] IBM quickly countered that Google's claim was exaggerated, and that the world's most powerful classical computer, the Summit OLCF-4 at Oak Ridge National Laboratory, could have performed the same calculation in 2.5 days.

IBM and others are working towards Quantum advantage (rather than supremacy), the point at which quantum applications deliver significant advantages over classical computers.[3] It announced progress earlier in 2019, when its 20 qubit processor doubled its previous record and produced a quantum volume of 16 with some of the lowest error rates reported. Quantum volume refers to the power of a QC, dependent on the number of qubits, their connectivity and coherence, together with gate and measurement errors, device interference and circuit design among other factors.

So size is not everything. Indeed, Sycamore is not even the largest quantum processor. Google itself has a 72 qubit processor and California start-up and recognized major player[4] in the quantum field, Rigetti is soon to launch a 128 qubit system.[5] While it is not know exactly when Quantum advantage or undisputed supremacy will be achieved, we believe it will support a quantum ecosystem, starting in the field of sampling, in which QCs transform capabilities of inference and pattern recognition in machine learning.[6] This could in turn support real business use cases, with potentially profound implications for academia, industry, defense and other areas.

Whether "supreme" or simply "super", Google's Sycamore QC announcement reminds us of the future of computing.

What is Machine Learning?

Machine Learning is a subset of Artificial Intelligence, which is the science of training machines to perform human tasks. ML is critically important in this endeavor (and others) in that it is responsible for cultivating the machine's learning capability by looking at patterns and drawing conclusions. ML refers to the cycle of asking a

[2] Arthur Herman, "The Quantum Computing Threat to American Security," Wall Street Journal, November 10, 2019. https://www.wsj.com/articles/the-quantum-computing-threat-to-american-security-11573411715?yptr=yahoo

[3] Larry Dignan for Between the Lines, "IBM hits quantum computing milestone, may see 'Quantum Advantage' in 2020s," March 4, 2019. https://www.zdnet.com/article/ibm-hits-quantum-computing-milestone-may-see-quantum-advantage-in-2020s/

[4] Peter H. Diamandis, "Massive Disruption Is Coming With Quantum Computing," October 10, 2016. https://singularityhub.com/2016/10/10/massive-disruption-quantum-computing/

[5] Chad Rigetti, "The Rigetti 128-qubit chip and what it means for quantum," August 8, 2019. https://medium.com/rigetti/the-rigetti-128-qubit-chip-and-what-it-means-for-quantum-df757d1b71ea

[6] Masoud Mohseni, Peter Read, Hartmut Neven, "Commercialize Early Quantum Technologies," March 9, 2017 at https://storage.googleapis.com/pub-tools-public-publication-data/pdf/45919.pdf

question, gathering data relevant to that question, designing an algorithm, testing that algorithm, collecting feedback, using the feedback to refine the algorithm and thereby improving performance.

The aim of ML is to develop continually improving machines that evolve with the data to produce reliable and repeatable decisions. The need for human interaction is steadily reduced as highly sophisticated, evolving algorithms are continually refined until they come to reflect human thought processes as closely as possible. Examples of ML already in use are recommendations made by online retail services (Amazon) or automatic credit ratings; but when combined with the potential achievement of quantum computing, the scope for other applications is vast.

Quantum Computing and Machine Learning applications

QC capability and ML advances will not only accelerate the processing of data, they could allow businesses, industries and governments to re-conceptualize analytic workloads, pursue new strategies and tackle new challenges. The earliest applications, some of which are already being developed, will most likely be in computationally intensive problems in finance, risk management, cybersecurity, materials science, energy, and logistics. These fields stand to benefit most from the **simulation**, **optimization** and **sampling** breakthroughs that QC may bring.

Applications:

1. **Governments** hold vast amounts of data, for example relating to utilities and public safety. Quantum methods could analyze and exploit this data more efficiently to increase efficiency, reduce costs and improve standards of living.
2. **Aerospace and Defense** establishments could benefit from QC advances through early adoption of more sophisticated computers and sensors to imaging technology and cybersecurity.
3. **Cryptography -** QCs could possibly be able to decode classically encrypted data. Hence companies and governments are already working to develop new quantum-based information-technology infrastructures to ensure that communications, banking and defense will remain secure in a quantum era.
4. **Financial service companies -** could use QC to identify insights in data and balance many competing factors for portfolio optimization (selecting assets and minimizing transaction costs), asset pricing, capital project budgeting, data security and fraud prevention.

5. **Healthcare** — thanks to personal devices that collect increasing amounts of information on individuals, QCs could spearhead the provision of personalized medicine. Drug discovery could also be enhanced by QC's ability to analyze and optimize unprecedented amounts of complex information on the human genome and properties of the natural world.
6. **Retail** — QC could transform retail in its ability to analyze buying history, make suggestions, optimize pricing and personalize the shopping experience. It could refine online recommendations and bidding strategies for advertisements using optimization algorithms to respond in the most effective way to consumers' needs and changing markets.
7. **Oil and Gas** industries could be enhanced through a QC contribution to the analysis of minerals in the ground to help find new energy sources, predict refinery sensor failures, and streamline oil distribution to make it more efficient and cost-effective.
8. **Transportation and logistics** could see wide applications of QC and ML technology – from the much-hyped self-driving car (the epitome of ML success in which the car "learns" to respond as a human would) to route-planning and optimization or flight-scheduling
9. **Materials Scientists** could use QC to help design new materials and industrial processes by precisely predicting the behavior of molecules. QCs could conduct chemistry simulations to improve batteries for electric vehicles or to develop new pharmaceuticals. They could synthesize the nitrogen reaction that makes fertilizer (and currently depletes the worlds' natural gas reserves); or make robotics more effective.

By the Numbers: Quantum Computing and Machine Learning Global Value Chain

QCs are not positioned to replace smart phones and laptops. Rather by 2030 it has been suggested that the technology supporting these and other devices will regularly be using QC accessed via the cloud, and that the market will continue to develop into the 2030s.[7]

Analysts have suggested that the early stages of a full QC market will be led by the Noisy Intermediate Scale Quantum (NISQ) computing market, which should be available soon.[8] While the biological and chemical sciences disciplines are likely to find this stage

[7] See Duncan Stewart for Deloitte, "Quantum computers: The next supercomputers, but not the next laptops. TMT Predictions 2019," Dec 11, 2018, at https://www2.deloitte.com/insights/us/en/industry/technology/technology-media-and-telecom-predictions/quantum-computing-supremacy.html

[8] Duncan Stewart for Deloitte, "Quantum computers: The next supercomputers, but not the next laptops. TMT Predictions 2019," Dec 11, 2018, at https://www2.deloitte.com/insights/us/en/industry/technology/technology-media-and-telecom-predictions/quantum-computing-supremacy.html.

the most serviceable, the fields of security and cryptography must be made quantum-safe before large QCs are finally developed to avoid significant liability and financial overhead in the future. Morgan Stanley have emphasized the far-reaching potential impacts of QC in a wide variety of spheres, from oil, gas and utilities to medicine, finance, aerospace, defense, AI, and Big Data. Based on their analysis, they envisage a doubling in value of the high-end quantum computing market (estimated by IBM at $5-6 billion a year in 2018).[9]

Specialists in this field suggest a strong future global market for QC hardware, separate from the software and services enabled by it. While QCs likely won't be superior to PCs in many areas, the niche for QC's contribution could become roughly equivalent to the contemporary supercomputer market (which also consists of large, non-portable million-dollar devices that are only capable of solving certain problems), which was worth about US$32 billion in 2017and continues to grow.[10]

Catalysts for growth

Based on CB Insights data and press releases, Deloitte has declared that "In the last three years, venture capital investors have placed $147 million with quantum computing start-ups; governments globally have provided $2.2 billion in support to researchers."[11] In our view this level of investment, combined with evidence of real progress from the scientists and considerable commitment among potential industrial and commercial operators, reflects significant market confidence in the future value of QC and ML.

Numerous IT giants have active quantum computing research programs, including Google, IBM, Intel, Hewlett Packard Enterprise, Microsoft, Nokia Bell Labs, and Raytheon. Alibaba, Google, and IBM in particular are working on hack-resistant encryption, software troubleshooting and ML. Barclays, Goldman Sachs, and other financial institutions are also examining the potential of QC in maximizing investment profits, forward planning and data security. In the aerospace field, Airbus is probing applications in communications and cryptography, while Lockheed Martin is advancing applications in verification and validation of complex systems and the development of ML algorithms. The US Navy pays for QC training and is working on algorithms for optimization problems such as data storage and energy-efficient data retrieval with

[9] Zayan Guedim, "Quantum Leap in Computing," October 12, 2018, https://edgy.app/11-companies-set-for-a-quantum-computing-leap. Note that the high-end QC market is just one sector within the investable universe of quantum computing and machine learning, not the primary focus of the QTUM ETF.

[10] See Duncan Stewart for Deloitte, "Quantum computers: The next supercomputers, but not the next laptops. TMT Predictions 2019," Dec 11, 2018, at https://www2.deloitte.com/insights/us/en/industry/technology/technology-media-and-telecom-predictions/quantum-computing-supremacy.html.

[11] David Schatsky, Ramya Kunnath Puliyakodil, "From fantasy to reality. Quantum computing is coming to the marketplace," April 26, 2017 at https://www2.deloitte.com/insights/us/en/focus/signals-for-strategists/quantum-computing-enterprise-applications.html

underwater autonomous robots.[12] Meanwhile the UK and European Commission have launched "national" QC strategies[13] and in the USA, Congress passed the National Quantum Initiative Act in December 2018. This is a ten-year plan, including $1.25 billion of funding over the first five years from the Department of Energy to support research and development in QC and promote industry participation.

While there is still a lot of fundamental science to be worked out and commercializing that science will take time, there is clear market confidence, resolution and investment on the part of the major scientific, industrial, governmental and commercial interests.[14] Analysts understand the QC market to be following Moore's Law, which forecasts historical trends in technological and social change, productivity, and economic growth.[15] This Law anticipates a continual series of performance improvements and declining costs in the market, just as occurred with classical computers in their earliest phases of innovation and development. According to this model, future stages of QC development will require scientific breakthroughs in the capacity, stability, and reliability of qubits and the programming and refinement of an environment that allows non-experts to interact with the technology. These developments are already playing out, with Strangeworks, an Austin USA-based start-up developing tools to ease researchers' transition from classical to quantum computing[16] and IBM reporting and anticipating even more advances in quantum volume.[17]

Analysts see "QC [as] one of the largest 'new' technology revenue opportunities to emerge over the next decade."[18]

[12] David Schatsky, Ramya Kunnath Puliyakodil, "From fantasy to reality. Quantum computing is coming to the marketplace," April 26, 2017 at https://www2.deloitte.com/insights/us/en/focus/signals-for-strategists/quantum-computing-enterprise-applications.html

[13] "ITIF Technology Explainer: What Is Quantum Computing?" September 20, 2018 at https://itif.org/publications/2018/09/20/itif-technology-explainer-what-quantum-computing

[14] Paul Teich for Tirias Research, October 23, 2017, at https://www.forbes.com/sites/tiriasresearch/2017/10/23/quantum-will-not-break-encryption-yet/#2b4a01207319

[15] "ITIF Technology Explainer: What Is Quantum Computing?" September 20, 2018 at https://itif.org/publications/2018/09/20/itif-technology-explainer-what-quantum-computing

[16] Strangeworks Company Website. https://strangeworks.com/

[17] Larry Dignan for Between the Lines, "IBM hits quantum computing milestone, may see 'Quantum Advantage' in 2020s," March 4, 2019. https://www.zdnet.com/article/ibm-hits-quantum-computing-milestone-may-see-quantum-advantage-in-2020s/

[18] See Duncan Stewart for Deloitte, "Quantum computers: The next supercomputers, but not the next laptops. TMT Predictions 2019," Dec 11, 2018, at https://www2.deloitte.com/insights/us/en/industry/technology/technology-media-and-telecom-predictions/quantum-computing-supremacy.html

Potential Benefits of ETF Investing:

The Defiance Future Technology ETF-QTUM:

- Offers investors liquid, transparent and low-cost access to companies developing and applying Quantum Computing and other transformative computing technologies.[19]
- Tracks approximately 60 globally-listed sticks across all market capitalizations, using the BlueStar Quantum Computing and Machine Learning Index (BQTUM)*
- Incorporates an equal weight methodology which offers investors more precise exposure, including to smaller companies with more potential for growth.[20]
- * BQTUM: The BlueStar Quantum Computing and Machine Learning Index is a rules-based index comprised of equity securities of leading global companies engaged in the research & development or commercialization of systems and materials used in quantum computing: advanced traditional computing hardware, high powered computing data connectivity solutions and cooling systems, and companies that specialize in the perception, collection and management of heterogeneous big data used in machine learning.

The Fund is distributed by Foreside Fund Services, LLC.

Fund holdings and sectors are subject to change at any time and should not be considered recommendations.

Percentage of Net Assets	Name
2.16%	CLOUDERA INC
2.07%	MAXAR TECHNOLOGIES INC
1.90%	CIRRUS LOGIC INC
1.76%	ULTRA CLEAN HLDGS INC
1.63%	STMICROELECTRONICS
1.61%	TOWER SEMICONDUCTOR LTD
1.59%	KLA CORP
1.59%	MKS INSTRUMENT INC
1.57%	LAM RESEARCH CORP
1.57%	NVIDIA CORP

[19] The possible applications of quantum computing are only in the exploration stages, and the possibility of returns is uncertain and may not be realized in the near future.

[20] Index components are assigned an equal weight subject to a liquidity overlay, index components are reviewed semi-annually for eligibility, and the weights are reset accordingly. Fund holdings and sectors are subject to change at any time and should not be considered recommendations to buy or sell any security. See the list of the fund's current top ten holdings.

**Commissions may be charged on trades.*

The Funds' investment objectives, risks, charges, and expenses must be considered carefully before investing. The prospectus contains this and other important information about the investment company. Please read it carefully before investing. A hard copy of the prospectus can be requested by calling 833.333.9383.

Investing involves risk. Principal loss is possible. As an ETF, the fund may trade at a premium or discount to NAV. Shares of any ETF are bought and sold at market price (not NAV) and are not individually redeemed from the Fund. The Fund is not actively managed and would not sell a security due to current or projected under performance unless that security is removed from the Index or is required upon a reconstitution of the Index. A portfolio concentrated in a single industry or country, may be subject to a higher degree of risk. The value of stocks of information technology companies are particularly vulnerable to rapid changes in technology product cycles, rapid product obsolescence, government regulation and competition. The Fund is considered to be non-diversified, so it may invest more of its assets in the securities of a single issuer or a smaller number of issuers. Investments in foreign securities involve certain risks including risk of loss due to foreign currency fluctuations or to political or economic instability. This risk is magnified in emerging markets. Small and mid-cap companies are subject to greater and more unpredictable price changes than securities of large-cap companies.

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