FUJITSU

Digital Annealer white book executive summary

What quantum (inspired) computing can achieve today and in the future

What would ‘quantum ready’ really mean?

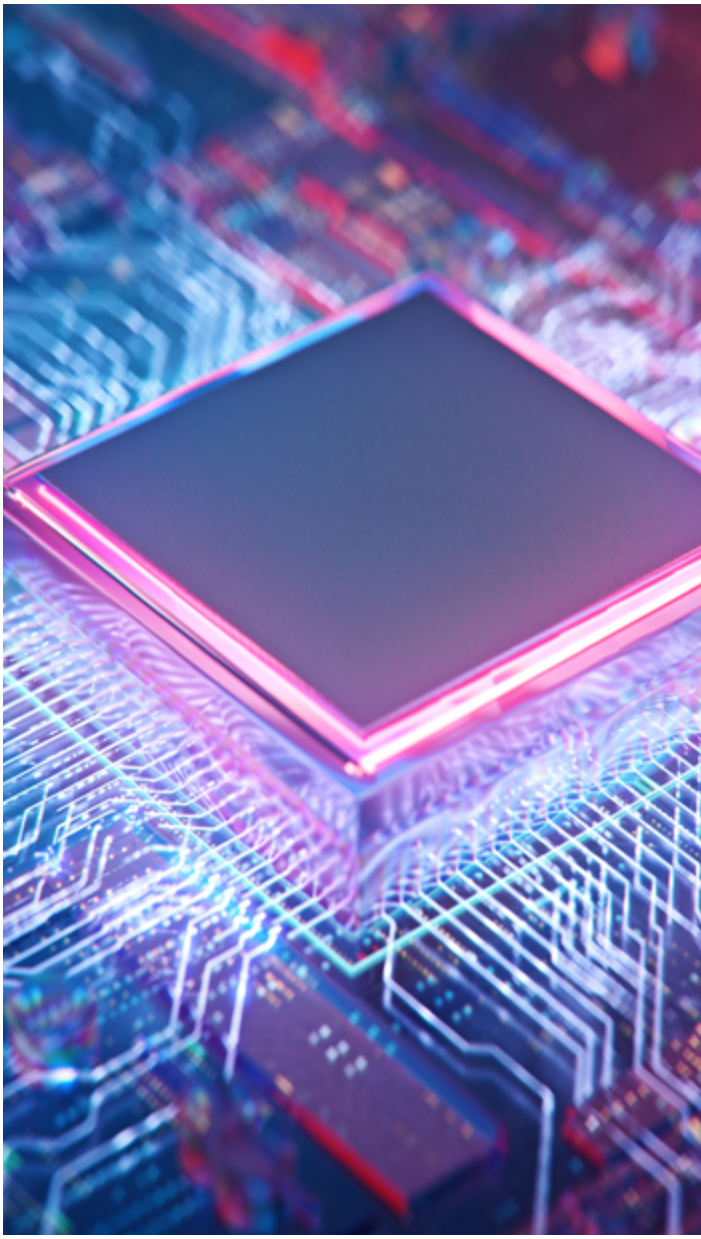
As quantum computing gains popularity and becoming one of the buzzwords of the decade, it’s important to take a step back and understand what it means to be ‘quantum ready’ and where we stand on the path towards a future based on quantum computing.

Despite the current uncertainty surrounding the commercial and practical viability of quantum computing systems and the timeline for solving real-world problems, it is widely recognized as a disruptive technology. Governments and IT companies are investing heavily in quantum technologies, anticipating exponential growth ratios not only for the technology itself but also for new applications and use cases. This has motivated companies to evaluate quantum computing today, either by integrating it into existing business processes or creating new ones. Consultancy-driven offerings, such as the Quantum Value Assessment & Acceleration, and quantum-inspired technologies are helping enterprises on their roadmap towards quantum computing and enabling them to solve complex combinatorial optimization problems.

Why quantum computing?

While it takes less than a second even on a PC to calculate the value of c by multiplying the two prime numbers below, the reverse task of finding the prime factors a and b for a given number is significantly more challenging. In fact, a classical supercomputer may need longer than the assumed age of the universe to find the solution. Those kinds of challenges where the compute time grows exponentially with the size and number of parameters (in the example above - the number of digits) can hardly or not at all be solved with classical computers. For some of the business challenges having those kinds of problems underneath, sufficient results may be achieved by simplifying the problem (e.g., taking only the most relevant input parameters into account) or not targeting the exact solution (e.g., looking for a very good local optimum instead of the global optimum). For others, this doesn’t work e.g., the prime factors of 15 are 3 and 5; 2 and 7 which equals 14 is close to 15 but doesn’t help at all.

The number of possibilities surges to new heights with each new connection and has already gone well beyond the capabilities of conventional computing. However, the emerging new classes of quantum and quantum-inspired computing are removing many of the current constraints, leading many Chief Technology Officers (CTOs) to look at the possibilities quantum computing has to offer.



Quantum computers are, in theory, capable of tackling such kind of business problems as they are based on the principles of quantum mechanics, such as:

Superposition

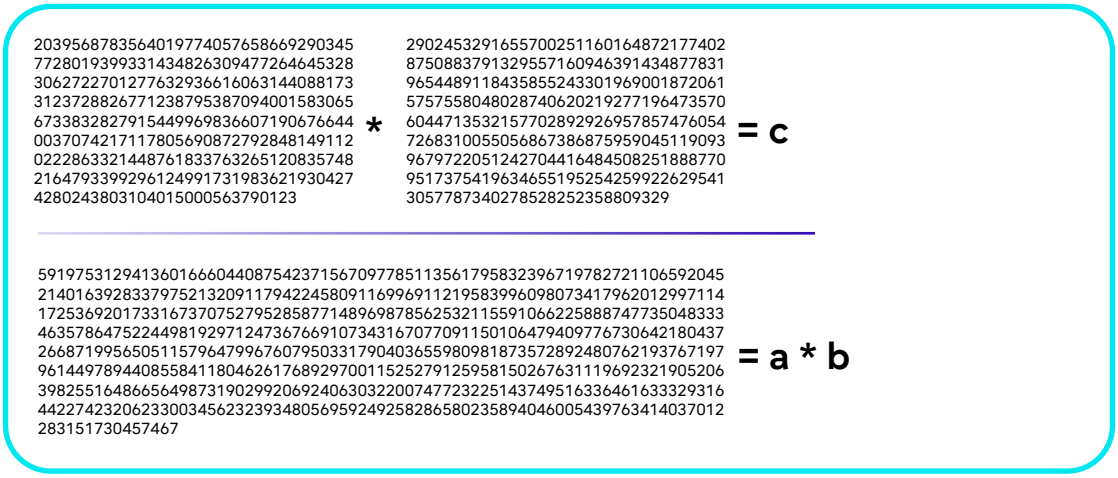
Whereas a classical computer bit can be either 0 or 1, a quantum bit (qubit) can be in all possible states, thus both '0' and '1' at the same time. When expanded to quantum memory, a 32-qubit quantum memory can be treated as if it were all 4,294,967,296 values at the same time.

Entanglement

A state in which 2 particles are connected and tied together irrespective of the distance between them.

Tunneling

A process in which a particle passes through a barrier that it classically cannot surmount. But quantum computers can't solve business relevant problems today. Today's quantum computers incorporate a few hundred qubits while the best known approach for the example above requires about 20 million qubits and 8 hours of compute time.*



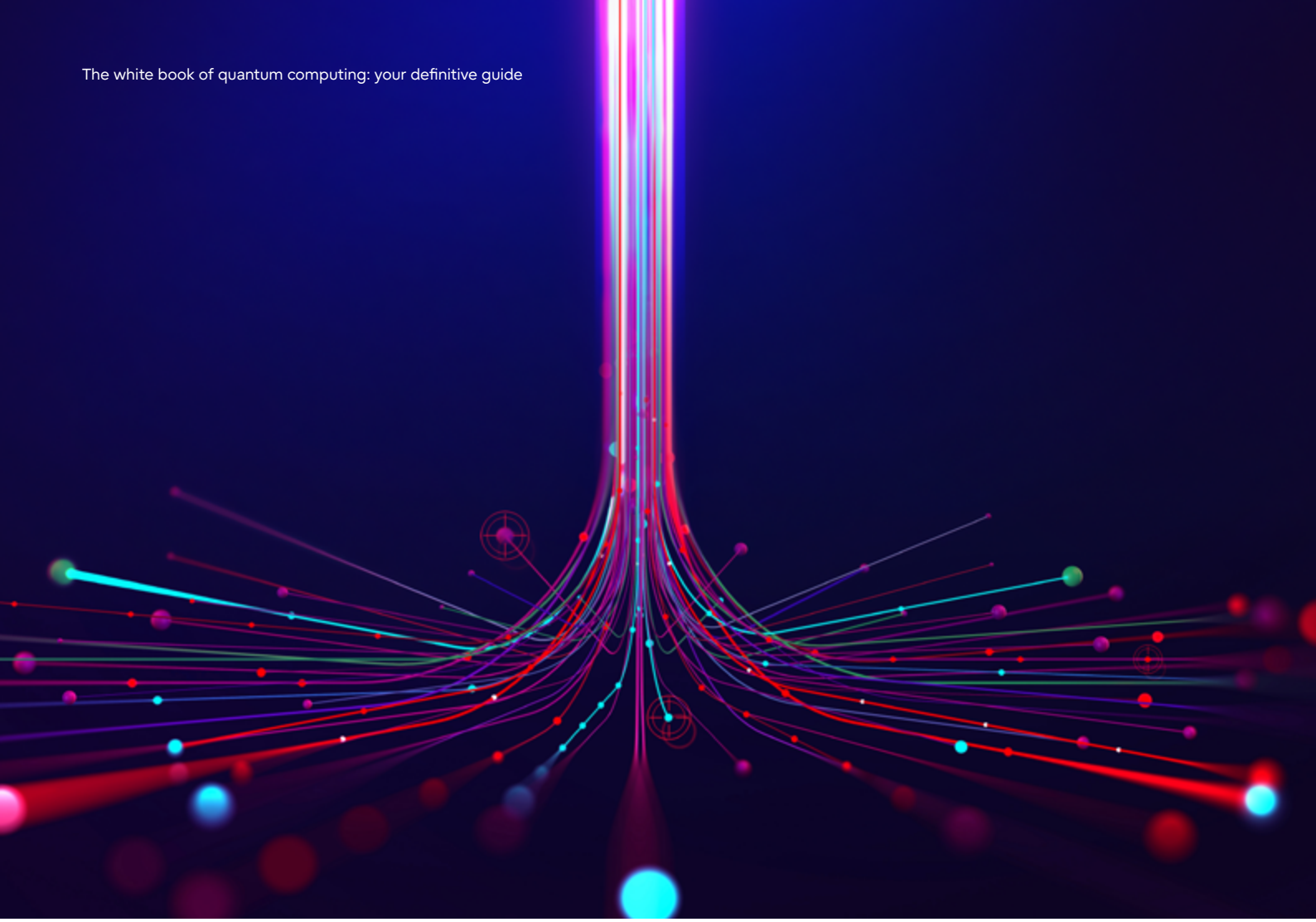
*: Physical qubits without error correction.
**: The problem represents decrypting a 2048-bit RSA encrypted information. Multiplying the two values in the upper box results in the value listed in the lower box.

What are enterprises expected to achieve with quantum computing?

Enterprises are often interested in developing new or enhanced offerings for their customers, as well as overcoming efficiency constraints. By using quantum computing, significant achievements are expected in both focus areas.

Material research, battery development, and personalized medicine are just a few areas quantum computing may provide significant value and drive further innovation. The car manufacturing industry has been quick to see and interrogate the possibilities of quantum computing. The challenge they face is existential. Author and economist Jeremy Rifkin believes, "20 years from now, car sharing will be the norm and car ownership an anomaly."

On the other hand, for achieving efficiency constraints, optimization is the way to go. Capacitated vehicle routing, engineer route planning, job shop scheduling, and energy distribution are just a few areas where quantum computing may provide better solution qualities in a shorter period. Additionally, quantum computing has proven to bring significant gains in terms of traffic light optimization as proven in a project with Hamburg Port Authority. Instead of locally actuated traffic lights, the whole grid of traffic lights in that area was considered for a global optimization approach. The outcome was an increase of up to 20% of the mean vehicle speed and a 9% reduction in CO_2 emission.



Future potential

The potential of quantum computing means the 'way it has always been done' can now be ripped up. For example, in the aerospace industry, manufacturers are investigating the potential of applying quantum technologies to challenges such as aircraft climb optimization, wing box design, aircraft loading optimization, satellite imagery analysis, and the development of new ultra-durable materials. This could have enormous potential commercial benefits for an industry where cost competition is fierce and environmental pressures are mounting.

Why isn't it ready yet?

Several types of quantum computers are being used for experimental testing—and the potential is awe-inspiring. But what are the challenges? Practical quantum computing remains in the distant future. Scalability to hundreds of thousands of qubits, cooling, and error correction are just a few challenges that need to be solved. But what is true for quantum computing isn't necessarily valid for quantum-inspired computing.

What is quantum-inspired computing?

Quantum-inspired computing is the use of computational methods inspired by the principles of quantum mechanics. Thus, instead of a true quantum computer with all its limitations in terms of operation conditions and inability to solve real world problems today, quantum-inspired computing relies on classical techniques through special purpose built hardware. The algorithmic approach and the programming itself are derived from quantum computing. A plain re-compilation of an existing application, e.g., C++, will work neither on a quantum computer nor on a quantum-inspired system. Instead, you must formulate the problem to be solved in a way those architectures can handle. A significant class of problems where quantum computers will provide new means are optimization problems.

The optimization problem is transferred into a kind of energy equation, and based on the quantum mechanical effects like tunneling, the quantum computer has the inherent logic to determine the minimum energy of such an energy equation which then represents the solution for the specific optimization problem. Quantum annealers are especially focused on solving combinatorial optimization problems. The term annealing originates from metal production. Metalworkers used forges to heat and hammer all kinds of metal, causing the layers of metal atoms to mesh very tightly. In physics, models describe this as a crystal of low inner energy, a state which is hard to change and which, for example, makes a sword blade extremely hard.

Simulated Annealing

This idea of energy minimization in metal annealing was then generalized to a 'simulated annealing' algorithm used to solve a wide range of optimization problems. When the algorithm has a target function (in our example, energy) and a range of possible outcomes, annealing is looking for an optimal state, which in this case would be minimal energy. Simulated annealing finds this by a random 'walk' through the possible outcomes while simultaneously cooling down the system.

Quantum Annealing

In quantum annealing, the system can tunnel through every finite barrier without having to go to higher energy. This is because the ground state (in our example, the lowest energy level) exerts the strongest attraction. Therefore, quantum annealing finds the global minimum more quickly and solves the optimization problem.

Digital Annealing

A convenient way to conceptualize the Digital Annealer is as a special accelerator to speed up combinatorial optimizations. It is also important to emphasize that it is not through quantum computing and therefore does not suffer from that technology's engineering and practical constraints. Fujitsu's Digital Annealer system architecture uses an architectural design inspired by quantum phenomena with logical connections across all bits. It can solve large-scale combinatorial optimization problems very quickly and, hugely important, more accurately than quantum annealing with its limited qubit connections.

Customer examples

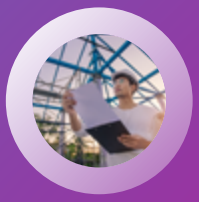
Digital Annealer (quantum-inspired computing)

Hamburg Port Authority: 20% Improved travel times of trucks in the supply chain and 9% CO_2 reduction by optimizing traffic light switching in the overall network.

Nippon Yusen Kabushiki Kaisha: Over 4,000 working hours saved per year, with streamlined car carrier stowage planning operations.

Deutsche Bahn: Optimization of timetable request approval, up to 10% more requests can be positively approved.

UK Space Agency: Space debris removal.



Field Service Management: Cut travel time by 25% with Fujitsu Field Force Optimization.

US Army Analytics Group: Covid-19 Personal Protective Equipment (PPE) provision optimization - 5X faster and 90% outperformance over a comparative evolutionary algorithm.

Preparing for the future

Fujitsu Digital Annealer has been described by independent analysts as a unique opportunity to preempt quantum computing and achieve the first-stage benefits of optimization, working within current data center constraints. It is an available future-proof on-ramp to quantum computing for solving real-world combinatorial optimization problems today.

With quantum computing estimated at still being 10 and 15 years away, it is both possible and advisable to start planning now. Quantum-inspired computing is available today and the Fujitsu Digital Annealer makes this practical and opens the door to the next quantum chapter.

How to get started?

Quantum Value Assessment & Acceleration: Delivering business value through quantum (inspired) technology

The Fujitsu Quantum Value Assessment & Acceleration (QVAA) offering is a unique and comprehensive approach to exploring the potential of quantum technology within enterprise organizations. The focus is not just on the technology itself, but on the business value that can be derived from its application. The approach is centered around structured, interactive workshops that are tailored to the specific industry. The workshops are facilitated by a multidisciplinary team including quantum computing consultants, digital advisors, and industry experts ensuring the outcome is relevant to the specific business context. The outcome of the QVAA is twofold. Firstly, it provides insight to provoke the right discussions within your organization. This comprehensive value assessment enables us to provide the right provocations, even when quantum may not be the answer.
Secondly, the QVAA results in validated and qualified opportunities that can be delivered in the short-term using quantum-inspired technology to accelerate towards new business value. A likely favorable outcome is a business case for a quick pilot that may facilitate further investment from within the business.

Quantum Value Assessment & Acceleration: Delivering business value through quantum (inspired) technology

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Get in touch with Fujitsu to join the journey towards creating the future!

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