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RESEARCH GROUP

Get Ahead of the Quantum Revolution

Keep track of a transformational technology as it evolves.

Quantum capability is about the journey of mastering quantum phenomena

"The quantum computing race is not about computing supremacy or digital dominance. Victory in the digital age will not be defined by geopolitical adversaries seeking to control the internet by manipulating information ordnance, but rather by centers of excellence forming across the world to master quantum mechanics for social benefits."

Adib Ghubril,

Director, CIO Research
Info-Tech Research Group

Executive Summary

Situation

- Our hyper-connected world, where commercial transactions and information exchanges routinely occur online, is predicated on the availability of secure communication channels.
- Machine learning is being applied across industries, particularly in pattern recognition applications, be it voice, image, or click-behavior, for digital personal assistants, transportation services, and online product support.

Complication

- The prevalent method for securing data payloads is, according to national security agencies, under clear, though still emerging, threat from quantum technologies.
- The neural network topology, which best supports a learning algorithm, is limited by classical computer architecture.
- Generic drugs are flooding the markets, putting ever downward pressure on margins, which hampers the development of innovative drugs.

Resolution

- Learn the key enabling components of quantum capability so that you can communicate how this technology works to the business.
- Adopt an approach to assess quantum capability to measure the progress of this technological innovation.
- Grow your emerging trends scanning practice by developing a foresight capability in IT.

Key research insights

Noisy Start

Quantum repeaters and quantum sensors may be considered noisy intermediate-scale quantum (NISQ) computers and their evolution is a prelude to full-scale quantum computers.

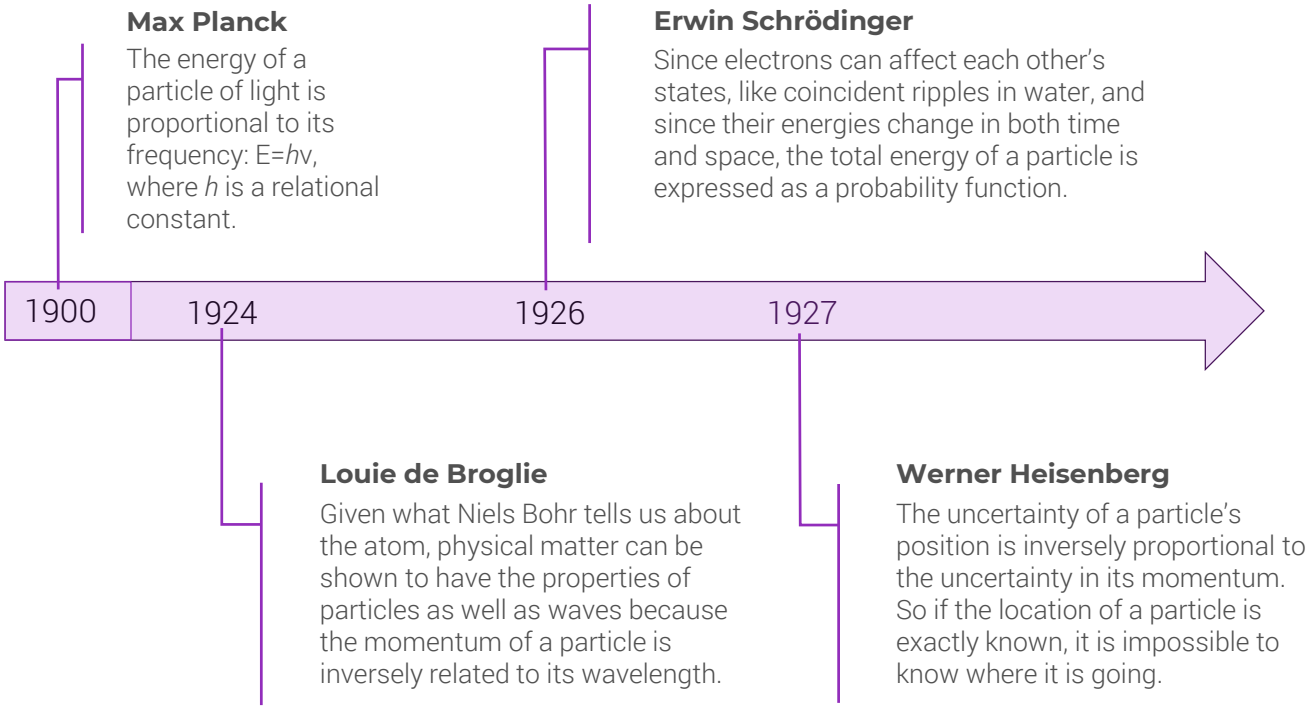
Natural Neural Nets

The pragmatic expectations scientists have about the use of quantum capability is telling of an advanced state of incubation that puts this technology on the verge of its growth stage.

Biopharma Is the Killer App

Modeling chemical processes to better understand cellular protein activity and accelerate advancements in cancer research, drug development, and genetic engineering is the killer app of quantum computing.

A brief history of quantum



Max Planck

The energy of a particle of light is proportional to its frequency: E=*h*v, where *h* is a relational constant.

Erwin Schrödinger

Since electrons can affect each other's states, like coincident ripples in water, and since their energies change in both time and space, the total energy of a particle is expressed as a probability function.

Louie de Broglie

Given what Niels Bohr tells us about the atom, physical matter can be shown to have the properties of particles as well as waves because the momentum of a particle is inversely related to its wavelength.

Werner Heisenberg

The uncertainty of a particle's position is inversely proportional to the uncertainty in its momentum. So if the location of a particle is exactly known, it is impossible to know where it is going.

How did we get here?

- The concept of quantum computing was first introduced in 1980 by theoretical physicist Richard Feynman, likely to express a desire for a processor that could model the behavior of molecules along with other biochemical interactions in nature.
- At the turn of the century a company, D-Wave, developed a means to encode quantum information – qubit – into silicon-based superconductors and used them to demonstrate how the system can search for unstructured data. That reinvigorated computer giant IBM's efforts to produce a quantum computer.
- The state of the art in quantum computing hardware is now at more than a hundred qubits (and more than 2,000 qubits for quantum annealers).

Quantum logic describes a set of principles based on the probability distribution of all possible states. This is conceptually similar to fuzzy logic, which is implemented in classical computing and describes a set of principles based on the probability of something being true or false.

Quantum Computing:

Driven by geopolitics

Why is it happening?

- The main motivation today is for the secret service of superpowers to devise methods that could break current cryptographic methods. This military-borne initiative has a parallel in the 1940s when means were sought to compute munition ballistics to improve the effectiveness of the gunnery. And just like in that time, when a group of powerful nations were juxtaposed, the quantum race is a symptom of a digital cold war.
- Still, we expect this understated geo-political power play to morph into something more grand. The distinct and immutable advantage quantum capability provides will not find its primary uses in information dominance but in improving human quality of life.

Quantum Computing:

A timely description

What is quantum computing?

Say Bob has a sports watch and Alice has a portable atomic watch. Bob's time-keeping device runs on the vibration of quartz crystal; it is digitally controlled and can count the number of minutes/seconds and milliseconds that elapse between set starts and stops; and it can accumulate time in a 24-hour cycle and track the days of the week.

Alice's device uses the vibrations of electrons generated by atoms made to resonate by being incident to electromagnetic waves. An electronic receiver measures the passing of seconds by counting the resulting electron vibrations. The very high rate of vibrations effectively allows the counter to delineate a period of many billionths of a second. Furthermore, the nature of the electron vibrations changes with altitude. This allows Alice to not only have the most accurate measure of time but also calculate her longitude and how far above or below the ground she is. Effectively, her atomic watch is a chronometer and altimeter.

Bob could use his watch to calculate his coordinates, if he stored enough data points, but it would essentially be impossible for him to compute his altitude. Both timekeeping devices use physical properties to measure cadence but one is at the crystal level, while the other is at the subatomic level. Both devices measure time but one is more practical and expedient for measuring speed and telling time and, while the atomic watch could also provide that information, the real gains are had when it is used to generate coordinates and calculate altitudes.

Bob's device is classical computing and Alice's device is quantum computing.

Quantum Computing:

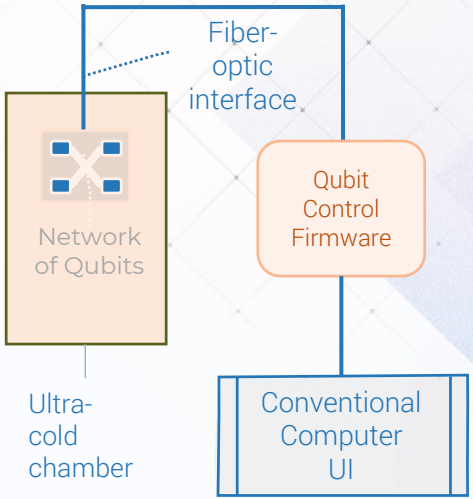
A technical description

What is quantum computing?

Quantum computers calculate using the spin properties of subatomic particles whereas classic computers use the charge properties of subatomic particles.

The electron, an example of a subatomic particle, exhibits both charge and spin. Classical computing hardware assigns a number 1 or 0 depending on whether the measured charge is above or below a threshold. Quantum computing hardware assigns a probability that an electron is in any particular spin state and proceeds accordingly.

Classical computing capacity is a factor of the complexity of the circuit imprinted on a microchip – the latest processors contain an equivalent of upwards of 400K gates. Capacity in quantum computers is measured solely by the number of quantum bits working in the system. Here logic gates don't exist in the ultra-cold chamber, they are pulses applied to the network of qubits from the control firmware.



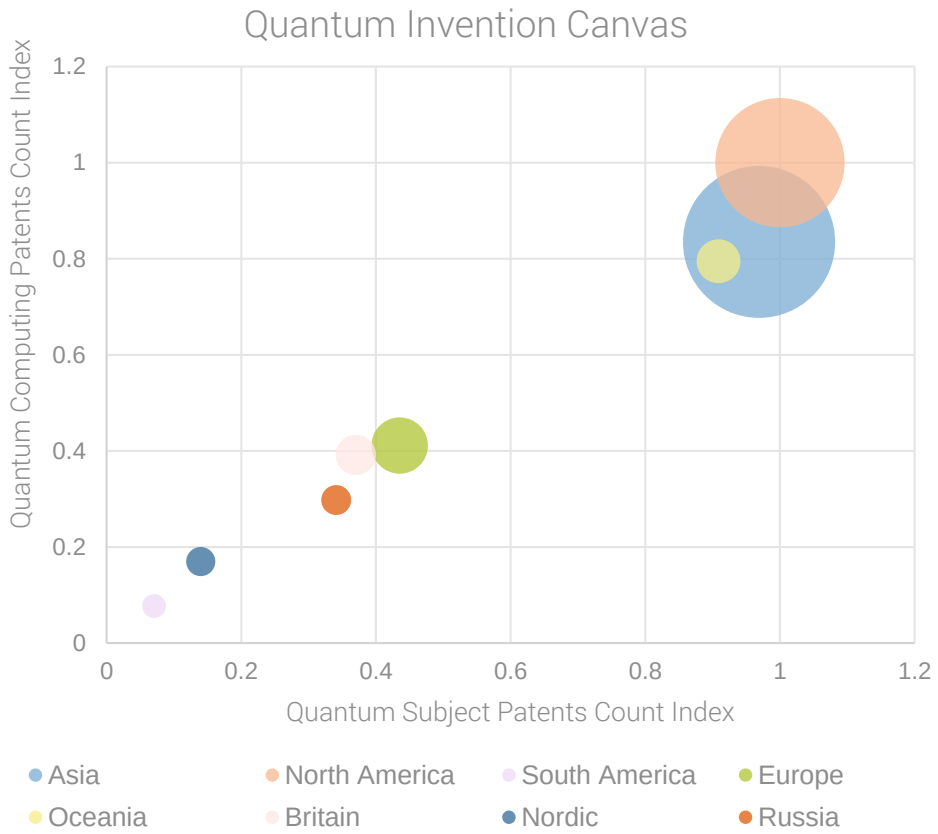
The Quantum Race

This is the second wave in the adoption life cycle of a technology. The research community is conducting proof-of-concept experiments and pursuing practical initiatives with near-term applications such as:

1. Quantum cryptography
2. Quantum metrology

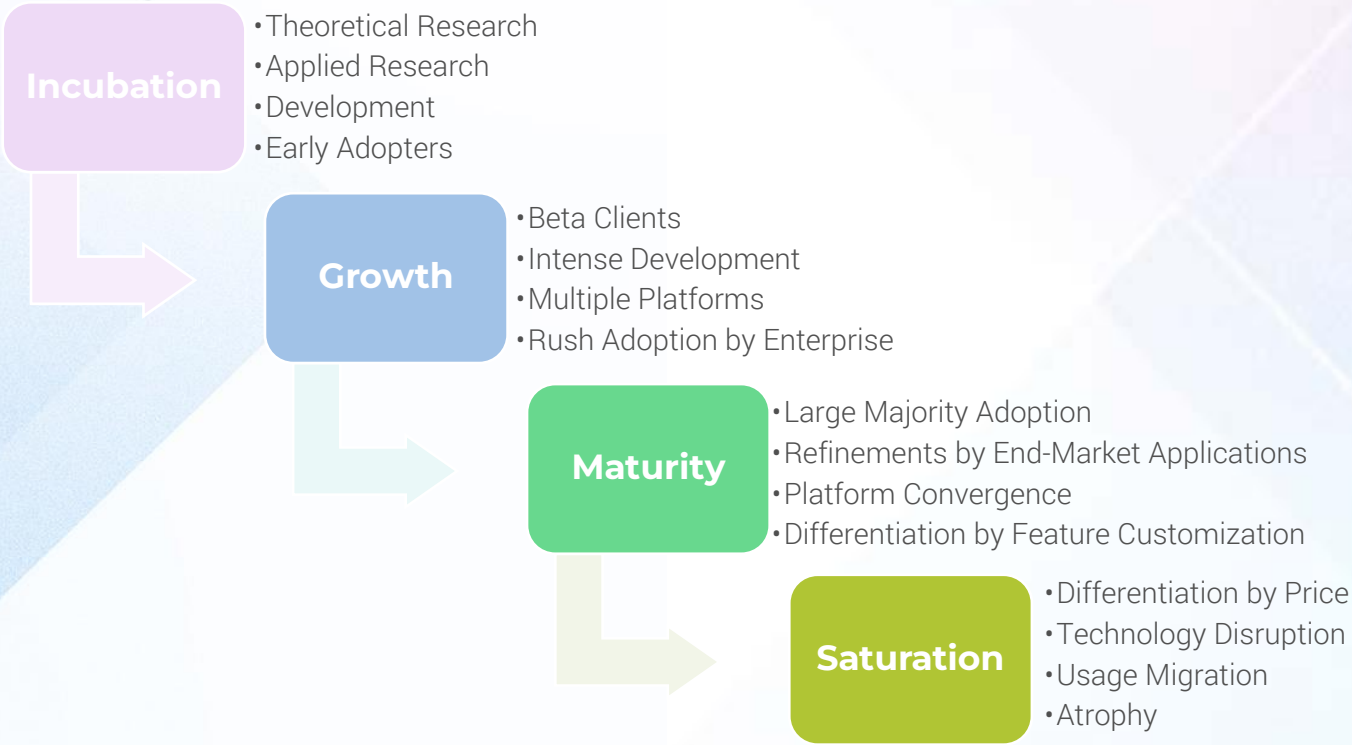
The Quantum Canvas (right) is a current snapshot of total invention capacity:

- Bubble-size represents relative figures of the latest rounds of funding
- X-axis is the normalized relative values of all patents awarded to-date in the field of quantum mechanics
- Y-axis is the normalized relative values of all patents awarded to-date in the field of quantum computing



Note: Oceania is defined in this way to highlight some collaboration amongst these countries

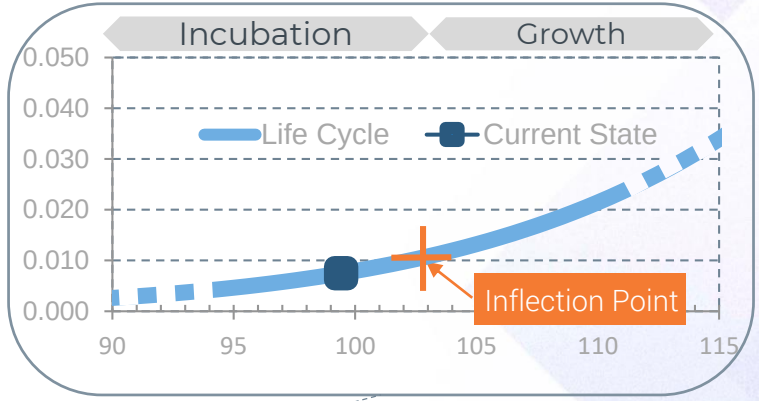
Forecasting Quantum Uptake: Stages of Evolution

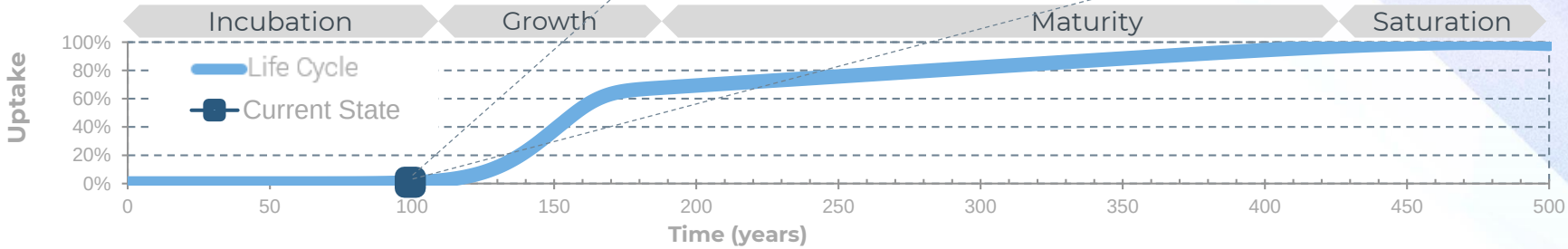


Quantum technology is at an inflection point

Key Assumptions

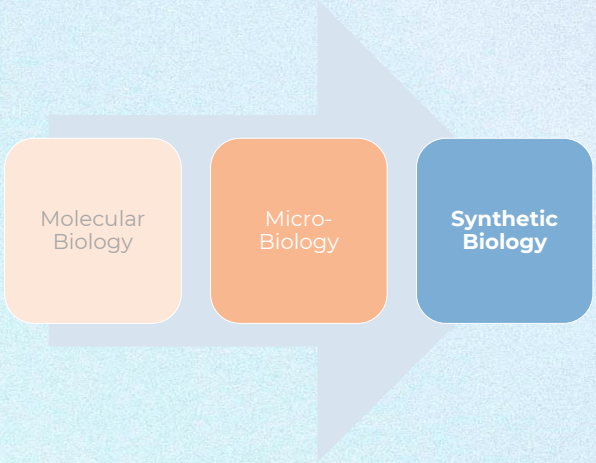
Quantum capability is a fundamental technology
Requires a very long-term view
Onset of quantum capability set at the year 1920
Plausible development scenarios
Improved network gear or hardware-as-a-service
Application announcement
Emerging qubit technology leader





What will the impact be?

Quantum capability enables a deeper understanding of biological systems:



Raised Economic Resilience

- Distributing cryptographic keys using quantum technologies will make it next to impossible for a third party to eavesdrop unbeknownst to the communicating parties.
- A more robust internet will better support “things” coming online and will engender trust among transacting parties.
- Improved trust in the internet will accelerate e-commerce, which will raise the velocity of money, which improves the resilience of economies worldwide.

Massive Machine Learning

- Entangled qubits act like nodes in a neural network: they can be made to recognize patterns in much the same way a neuromorphic computer architecture does.
- Quantum-based network topologies offer massive parallelism, via a higher degree of inter-nodal interaction, resulting in much improved machine learning.

Better Biotechnology

- Chemical processes are best studied at the atomic level; this requires modeling electron spin, which is a very complex undertaking when considering the aggregate interaction between the various atoms of the interacting molecules. Conventional computing fails beyond the simplest models (a coffee molecule).
- Quantum computing works on the state of atomic particles and can thus provide insights into those interactions. Those insights will help provide a deeper understanding of diseases and improve drug development.
- Beyond that, greater strides can be taken in genetic engineering and, ultimately, synthetic biology, which will lead to smart materials and augmented human performance.

Return Tradeoff

Risks

The principal risk is getting the timing wrong or focusing on two out of the three main hardware technologies that do not keep meeting improved qubit performance benchmarks.

Enterprises that maintain an early-adopter strategy must get onto the technology now because all signals are suggesting that the next 3-5 years are expected to bring meaningful, positive changes to the field.

But if those changes are not forthcoming and it takes another 3-5 years or the hardware technology they're banking on falls through, their stuttered start will prove costly.

Benefits

The biggest return on increasing quantum capability is the marked improvement expected in genetic engineering.

Beyond that, enterprises that take a stake in developing the quantum platform, particularly those working at the firmware and software layer, stand to gain a significant competitive advantage ahead of the onset of the growth stage, an advantage that could last for most of the growth stage period.

Still, that head start will not be as long as the one for companies who worked on the hardware layer of the platform, and picked the winning qubit technology, but it will not be nearly as risky either.

Learn, Assess, and Grow

Use Info-Tech's resources to support you on your journey.

01

Learn

The Basics of Quantum Capability

Develop an understanding of the fundamental characteristics of quantum mechanics so that you can begin to educate your stakeholders on how it works.

02

Assess

The Current Maturity of Quantum Capability

Determine the maturity level of this technology to inform how your organization should react to it, track its progress, and stay ahead of the opportunity.

03

Grow

Your Emerging Trends Practice

Build a strategic foresight capability in IT so that IT becomes a leader in technological innovation for the organization.

"There has perhaps never been a time in human history where strategic foresight is more needed."

– Andy Hines,

Assistant Professor,

University of Houston

Future-proof your IT strategy with a Tech Futures Workshop

Whether your focus is adopting a specific trend or building a corporate foresight capability, a **Tech Futures Workshop** can be adapted to suit your needs. Contact your account representative or email Workshops@InfoTech.com for more information.

	Workshop Day 1	Workshop Day 2
Activities	**Kick-off and Signal Gathering** **1.1** Foresight process primer and discussion **1.2** Trend-specific education session and discussion **1.3** Signal gathering and research **1.4** Cluster signals into trends	**Scenario Building and Ideation** **2.1** Brainstorm potential use cases (ideation) **2.2** Assign probabilities to scenarios **2.3** Conduct wind tunneling exercise **2.4** Select idea/use case **2.5** Map the user journey for prioritized use cases
	Identify Trends and Uncover Drivers **1.5** Analyze and select trend impact **1.6** Perform causal analysis **1.7** Select key drivers **1.8** Build a scenario canvas	**Action Planning and Process Design** **2.6** Discuss adoption readiness **2.7** Document a process for strategic foresight **2.8** Assign roles and responsibilities **2.9** Document an action plan to roll out the process
Deliverables	1. A set of signal items ready for analysis 2. A collection of relevant trends, with a key trend selected 3. A set of drivers influencing the key trend, with primary drivers selected	1. A set of plausible scenarios for planning purposes 2. A potential strategic initiative that is ready to move into prototyping 3. A custom trends brief document 4. A defined process for applying strategic foresight in your organization