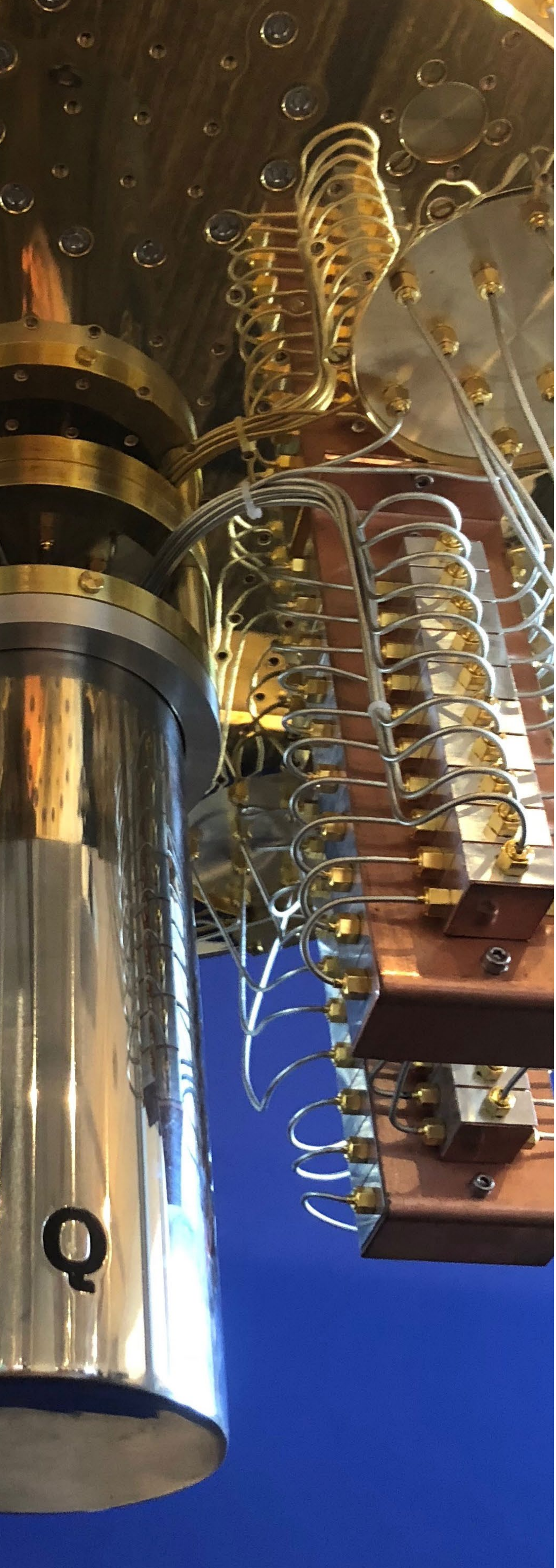

Expert Insights

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Exploring quantum computing use cases for manufacturing

IBM **Institute for Business Value**

Experts on this topic

Dr. Roman Malina

IBM Q Consulting
Global Leader Manufacturing
IBM Services
linkedin.com/in/roman-malina
roman.malina@ch.ibm.com

Dr. Roman Malina leads global manufacturing in the IBM Q consulting organization. He helps clients develop their strategies, approaches, and specific use cases for quantum computing. With 20 years of cross-industry experience, he has consulted with numerous clients on strategy and enterprise architecture.

Dr. Stefan Woerner

Global Leader
Quantum Finance and Optimization
IBM Research
linkedin.com/in/stefan-woerner
WOR@zurich.ibm.com

Dr. Stefan Woerner is the Global Leader for Quantum Finance & Optimization and a Research Staff Member in the Quantum Technologies group of the Science & Technology department at IBM Research - Zurich. The focus of his research is the development and analysis of quantum algorithms for optimization and machine learning and their practical applications, particularly in finance.

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Talking points

Enormous potential
Quantum computing is expected to help develop breakthrough products and services that will disrupt and redefine manufacturing.

Business advantage
Chemical discovery, product development, and process optimization are among the manufacturing areas likely to witness major innovations with quantum computing.

Substantial impact
Early adopters have the opportunity to lock in advantages that will be enormously difficult to challenge.

Simulating nature

"Nature isn't classical . . . and if you want to make a simulation of Nature, you'd better make it quantum mechanical, and by golly it's a wonderful problem, because it doesn't look so easy."[1] With these words in 1981, Richard Feynman gave birth to the idea of harnessing quantum mechanical phenomena for computing. He was right—it wasn't so easy. But now, nearly four decades later, quantum computers are finally being built and tested.[2]

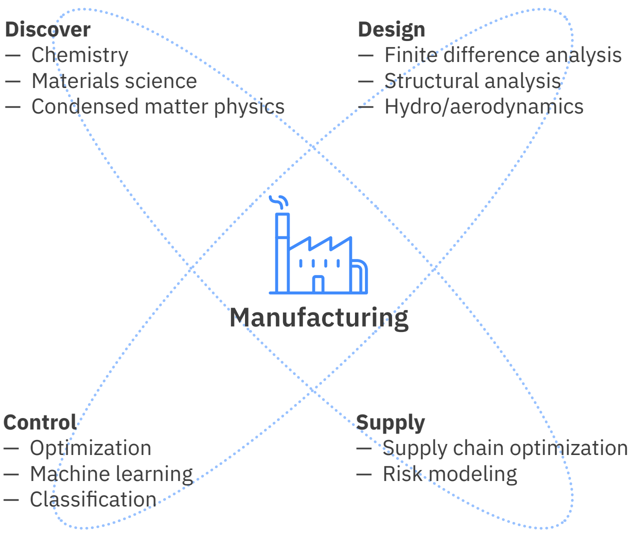
Quantum computing's potential is enormous. While the power of a classical computer can be approximately doubled by doubling its number of transistors, the power of a quantum computer can be approximately doubled by adding one qubit.

While many broad commercial applications remain several years away, manufacturing is a candidate to be one of the main early beneficiaries of quantum computing through breakthrough products and services and redefined operation. Most use cases for quantum computing in manufacturing can be captured by using the taxonomy in Figure 1.

If and when a quantum computer is built using 275 qubits, it could represent more computational states than there are atoms in the known universe.[3]

Figure 1

Categorizing potential quantum computing use cases in manufacturing



Here, we explore potential use cases for manufacturing in each of four categories – discover, design, control, and supply:

Discover

It's no secret that today's classical computers struggle with modeling even moderately sized molecules with complete chemical accuracy. Quantum computing, with its exponentially large state space, should provide comprehensive modeling of very sophisticated molecules that can dramatically benefit materials and drug development.

Today, there are about 15 million known chemical structures and 300,000 materials.[4] Many more beneficial substances wait to be discovered. Every day, nature produces materials with astonishing properties that industrial manufacturing processes can't duplicate. For example, by weight, spider silk is stronger than steel and is made at body temperature rather than forged in a furnace. Its production generates only water as a by-product. Because spider silk is a protein made by DNA, quantum computing's superior ability to model at a subatomic level might someday translate into our ability to manufacture a similar or enhanced material in an equally eco-friendly way.[5]

Within the manufacturing realm, when quantum computing's predicted capabilities come to fruition, automotive, aerospace, and electronics industries could benefit from:

- Materials with more advantageous strength-to-weight ratios
- Batteries that offer significantly higher energy densities
- More efficient synthetic and catalytic processes that could help with energy generation and carbon capture.

Design

Today, many products are designed and pre-tested using computer simulation. Automotive and aerospace hardware components and subcomponents are 3D-modeled with individual engineering safety margins. These margins can accumulate, culminating in products that are over-engineered, overweight, or higher cost than necessary, which can stifle their commercial viability.

But, future quantum computers are expected to be able to simulate component interactions within complex hardware systems, more precisely and comprehensively calculating system loads, load paths, noise, and vibration. This integrated analysis can optimize the manufacturing of individual components in the context of the overall system, reducing the cumulative impact of numerous individual safety margins and improving cost without sacrificing overall system performance.[6]

Control

Modern control processes in manufacturing test the limits of advanced analytics, especially when employing machine learning and analyzing multiple variables. Quantum computing might help find new correlations in data, enhance pattern recognition, and advance classification beyond the capabilities of classical computing. The combination of quantum computing and machine learning, as well as its application to optimization, is expected to have significant impact in manufacturing in several areas:

- Semiconductor chip fabrication already uses machine learning and simple multi-variable analysis. But, classical computing has hit a computational wall and can't increase the number of factors for more complex analysis. It's expected that quantum computing might analyze additional interactive factors and processes to increase production yield.
- Production flows and robotics scheduling for complex products, such as automobiles, are highly complex, and their simulation and optimization is very compute intensive. Quantum computing might enable faster optimization runs and allow production to perform optimizations more dynamically.
- As product functionality becomes increasingly software-defined, quality control for software development relies on progressively sophisticated software validation, verification, and fault analysis. A modern high-end car might have 100 million lines of code, even more than a new commercial airliner.[7] Future quantum computers should have the capability to analyze software systems substantially more complex than classical computers could possibly evaluate today.

Bits and Qubits

In classical computing, the bit is the basic unit of information with only two possible states: 0 or 1. In contrast, the qubit is the basic unit of quantum information. A qubit can be in superposition of 0 and 1, allowing it to represent more information than a classical bit. A quantum computer's exponentially sized state space is then created through the entanglement of qubits with each other.

Supply

Supply chains are shifting from a linear model with discrete, sequential, event-driven processes to a more responsive organic model based on evolving real-time market demands and up-to-the-minute availability of key components. Adding to the digital supply chain toolbox of Industry 4.0, quantum computing potentially could accelerate decision-making and enhance risk management to lower operational costs,as well as reduce lost sales because of out-of-stock or discontinued products. Enhancing competitive agility, quantum computing might completely transform the supply chain over time, adaptively redesigning it to optimize vendor orders and accompanying logistics using dynamic near-real-time decision-making based on changing market demands.

More than a quadrillion

The largest quantum computers have around 50 qubits, giving them about 2^50 computational states. “Two to the fifty” equates to a state space of 1,125,899,906,842,624 states. This means that quantum computers might be able to use solution spaces many orders of magnitude larger than even the most powerful classical supercomputers.

Better, faster, safer production

Quantum computing is set to become a key instrument of transformation for manufacturers. With its anticipated impact on product development and design, manufacturing processes, and supply chain activities, it might provide a decisive edge to early adopters who embrace their quantum future now.

How can a manufacturer get started?

1. *Challenge quantum champions* in your organization to experiment with actual quantum computers and explore the potential applications of quantum computing for your specific industry. To help focus on your highest-value problems, have your quantum champions report to a quantum steering committee that includes line-of-business executives and market strategists.
2. *Prioritize potential quantum computing use cases* according to their potential for attaining business advantage—given your organization's business strategy, associated customer value propositions, and future growth plans. Keep an eye on progress in quantum application development to stay in the vanguard of which use cases might be commercialized sooner rather than later.
3. *Consider partnering with an emerging quantum ecosystem* of like-minded research labs and academic institutions, quantum technology providers, quantum application developers and coders, and start-ups with supporting technologies. Include organizations with similar challenges to gain immediate access to an entire quantum computing stack capable of developing and running quantum algorithms specific to your business needs. Look for breakthroughs in quantum technology that might necessitate a change in ecosystem partners.

Key questions to consider

» From which organizations within your business are you identifying champions charged with exploring the potential benefits of quantum computing?

» Which manufacturing quantum use cases might be of advantage your business?

» What is the opportunity cost if you don't begin exploring quantum computing use cases applicable to your business now?

About Expert Insights

Expert Insights represent the opinions of thought leaders on newsworthy business and related technology topics. They are based upon conversations with leading subject matter experts from around the globe. For more information, contact the IBM Institute for Business Value at iibv@us.ibm.com.

IBM Corporation
New Orchard Road
Armonk, NY 10504
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