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A Quantum Leap for Aerospace Simulations

GET THE COMPETITIVE EDGE WITH ACCELERATED, EFFICIENT SIMULATIONS.

INSIGHT PAPER

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Redefining Simulations

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Redefining simulations powered by Quantum Algorithms

Quantum Computing	Vs	Classical Computing
Calculates with qubits, which can represent state 0 and state 1 at the same time.	>	Calculates with transistors, which can represent either state 0 or state 1.
Computational power increases exponentially in proportion to the number of qubits.	>	Computational power increases in a 1:1 relationship with the number of transistors.
Well suited for tasks like optimization problems, data analysis, and simulations.	>	Classical computers best handle most everyday processing.

- Simulations powered by quantum algorithms offer immediate benefits, including fewer iterations and reduced compute costs. This aids aerospace innovation and time-to-market.
- The speed advantage of quantum computing arises from qubits representing state 0 and state 1 simultaneously, enabling efficient multidimensional simulations.

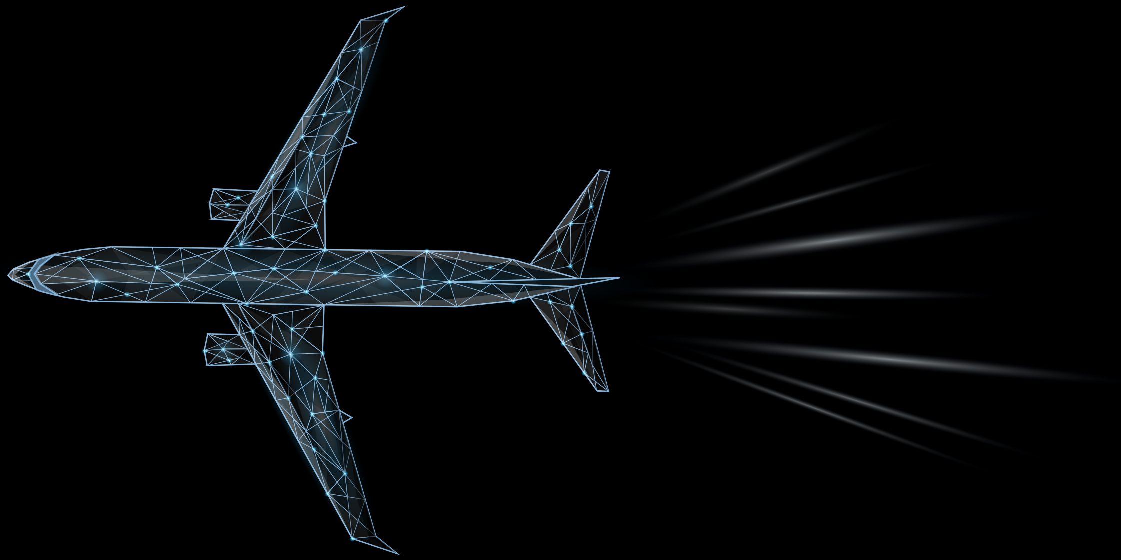
Quantum algorithms based on principles of quantum mechanics significantly accelerate complex problem-solving, like optimization and swap tasks, traditionally demanding for classical systems.

Solving Complex Simulations Faster

Design engineers can now experience quantum benefits with existing computing platforms

Here's how:

- Lower runtime costs for highly complex simulations
- Faster convergence.
- Requires significantly fewer computational resources for optimization problems than the classical methods.
- Reach global minima in fewer iterations
- Superior optimization outcomes, reaching global minima instead of local



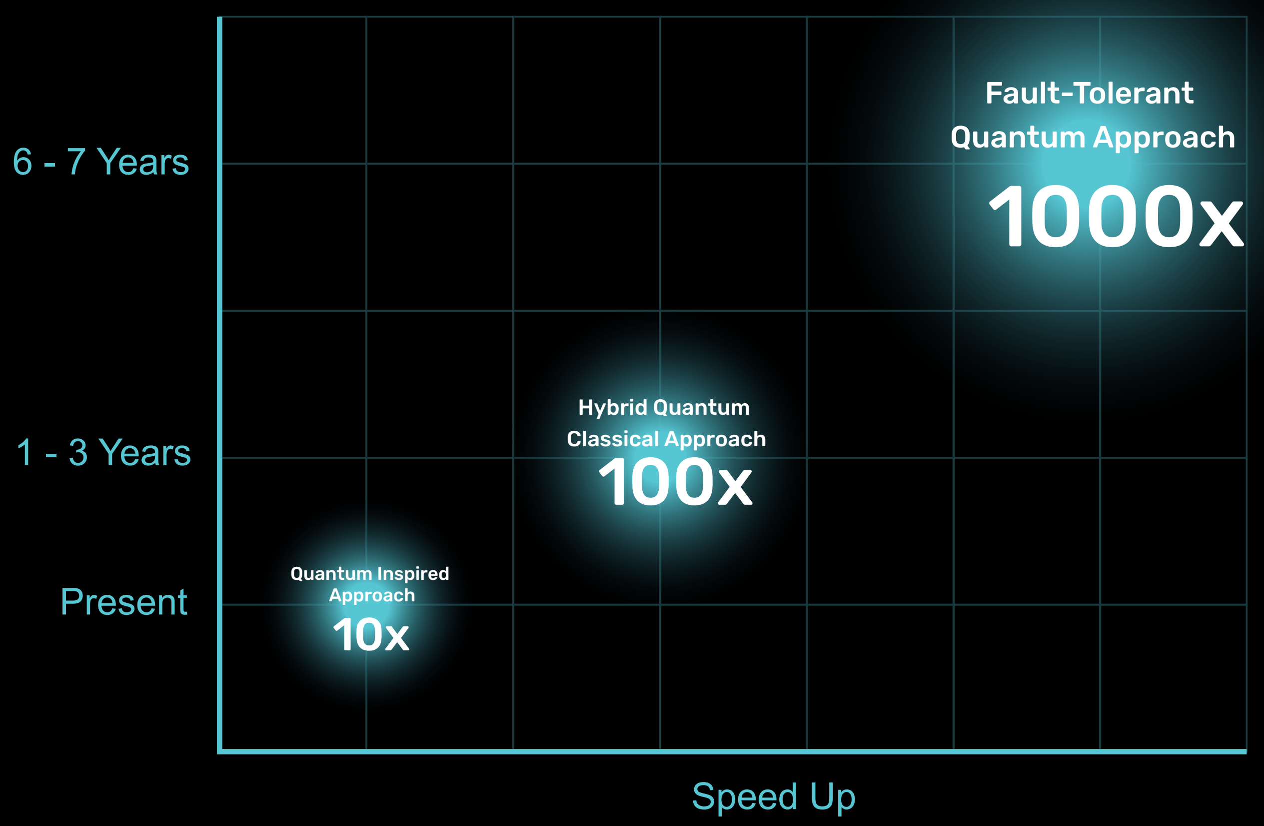
Overview: Quantum Computing For Engineering Simulations

- Large-scale fault-tolerant quantum computing has yet to mature fully.
- Development of Hybrid Quantum Classical (HQC) algorithms that use classical processing is still in progress.
- Quantum-inspired algorithms, which use classical algorithms to imitate the fundamental quantum phenomena to enhance computation, are the way forward before the transition to hybrid and full Quantum.

The aerospace industry is exploring potential applications for quantum computing with a particular focus on simulation as one of the key areas of interest.

Get Quantum ready today

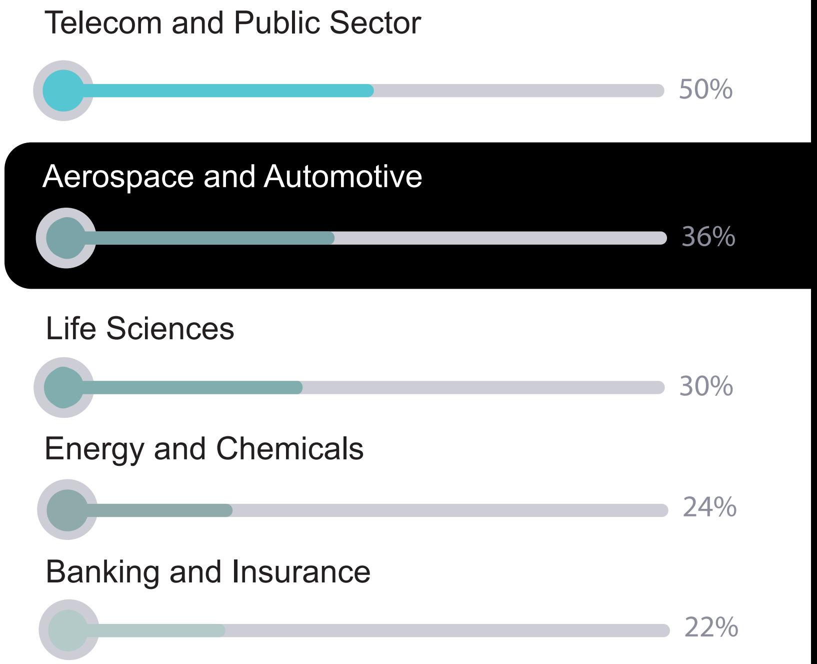
Expect 1000x results as Quantum Matures

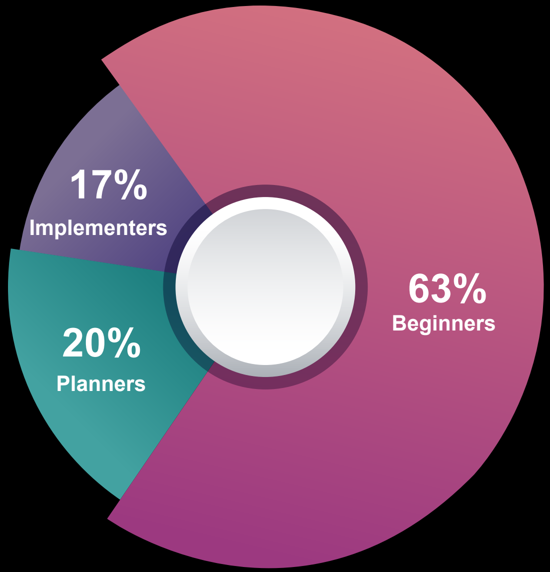


Current State of Quantum Adoption by Aerospace Industry

43%

Of organizations working on quantum technologies expect them to become available for use in at least one major commercial application within the next 3-5 years.





- Started research to understand the fundamentals of Quantum Technologies.
- Identifying the most appropriate problems to solve with Quantum Technologies.

- Identifying the right problems and are now integrating Quantum Technologies within our techy/R&D agenda/roadmap.

- Launched limited-scale pilots/proofs-of-concept on Quantum Technologies.
- Identifying the most appropriate problems to solve with Quantum Technologies.
- Achieved promising early results from experimentation with Quantum Technologies.

Major Players In Quantum Computing Tech

QUANTUM SYSTEMS, SOFTWARE, AND SERVICES

Quantum Annealing Syatems

D-Wave (The Quantum Computing Company), NEC

Superconducting Gate Quantum Computing

IBM, rigetti, HYUNDAI, amazon, FUJITSU, IQM, OQC, QILIMANJARO QUANTUM TECH

Trapped Ion Quantum Computing

CQC, Honeywell, IONQ, AQT, oxford ionics

Photonic

XANADU, PsiQuantum

Neutral Atom

atom computing, PASQAL

SOFTWARE AND SERVICES

BosonQ Psi, QCWARE, 1QBit, river lane, rigetti, IBM, amazon, Microsoft, MULTIVERSE COMPUTING, CLASSIQ, HYUNDAI

CLASSICAL SYSTEMS

Simulated Quantum Computing

IBM, amazon, Microsoft, Atos, NVIDIA

Quantum Inspired Computing

FUJITSU, Microsoft

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Megatrends In The Evolving **Aerospace Industry**

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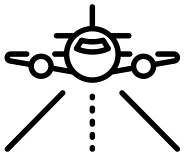
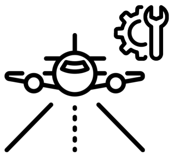
Key Trends Growing Complexity In Aerospace Industry

Zero-Emission Aircrafts



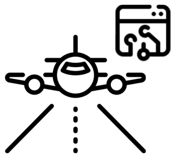
Aircraft manufacturers aim to significantly reduce or eliminate the need for traditional fuel sources by utilizing alternative power sources such as Hydrogen and Electric propulsion systems.

Digitalization and Advanced Manufacturing



This includes the use of technologies such as additive manufacturing (3D printing), robotics, automation, and advanced materials. Digitalization (digital twins) and advanced manufacturing enable more efficient and precise production processes, reduce costs and allow for the creation of complex and optimized aerospace components.

Maintenance, Repair, and Operations



This includes the use of predictive maintenance, surface defect technologies, sensors, and data analytics to monitor and optimize the performance of aircraft and enable proactive maintenance to enhance safety, reduce downtime, and optimize maintenance processes.

Megatrends : A timeline of Rising Aerospace Complexity

Near Future (3 - 5 Years)	Long - Term Future (5 - 10 Years)	Far Future (10+ Years)
Adoption of advanced materials for lightweight and durable aerospace components.	Exploration of nanomaterials, such as carbon nanotubes and graphene to create ultra - lightweight yet exceptionally strong structures for spacecraft and components.	Implementation of self-healing materials capable of autonomously repairing damage caused by environmental conditions.
Research on electric and hybrid-electric propulsion for short-haul flights.	Widespread use of electric aircraft for regional travel. Increased focus on hydrogen-powered and sustainable aviation.	Development of supersonic and hypersonic commercial air travel.
Enhanced situational awareness through AI-powered systems for collision avoidance, route optimization, and adaptive flight control.	Intelligent assistance to pilots in complex decision-making scenarios. Integration of natural language processing and gesture recognition for intuitive pilot-AI interactions.	AI-driven flight control systems for hypersonic aircraft, managing extreme speeds and dynamic flight conditions.

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Zero-Emission Aircrafts

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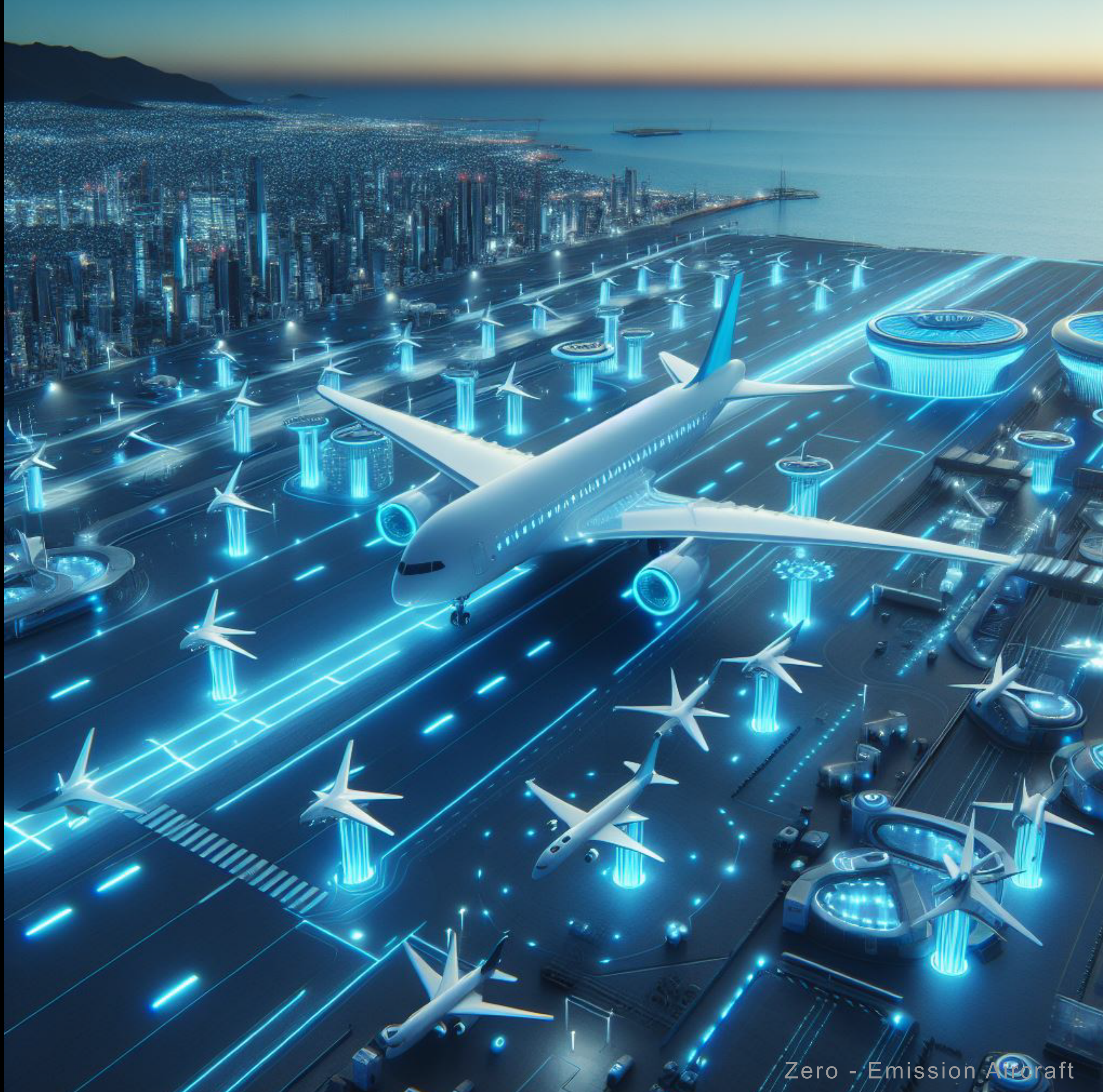


Simulations powered by Quantum Algorithms for building Zero Emission Aircraft

Zero-emission aircrafts need high performance designs demanding accurate and multidisciplinary design optimization techniques & coupled simulations powered by Quantum Algorithms.

Aerodynamic Simulations :
This includes assessing lift and drag characteristics under various flight conditions.

Structural Analysis :
Usually, Finite Element Analysis (FEA) is used to simulate the stress, strain, and deformation of aircraft components under different loads and boundary conditions.

Regenerative Cooling :
Thermal simulations may focus on regenerative systems that capture and reuse waste heat to improve overall efficiency and reduced energy requirements.

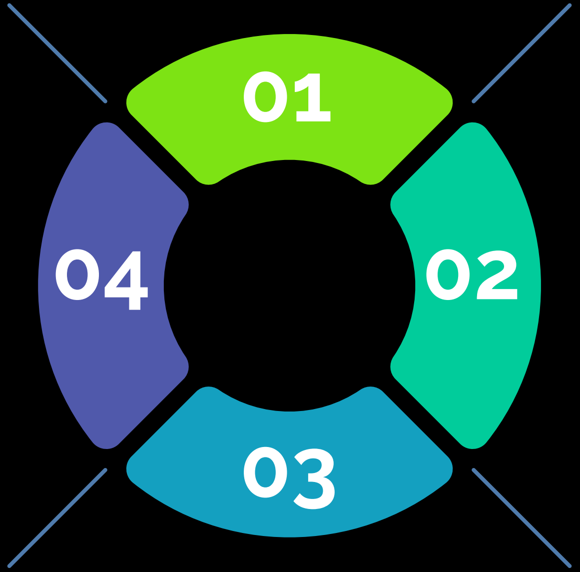
Propulsion Simulations:
Multi-domain simulations, combining mechanical, electrical, and thermal simulations, for optimizing the overall efficiency of the propulsion system.

Building efficient power trains with Simulations powered by Quantum Algorithms

The only viable approach to achieving a balance between performance, fuel efficiency, and environmental objectives in a single package is to simulate powertrain design in aircraft.

Powertrain Integration :
Multiphysics simulations coupling various physical domains, such as mechanical dynamics, electrical circuits, and thermal systems.

Electric Motor and Drive System Simulation :
Modeling electromagnetic and thermal behavior of electric motors. Dynamic simulations are used to understand the response of the motor-drive system under different conditions



Battery Performance Simulation:
This aids in optimizing the battery management system and overall energy storage efficiency.

Control System Simulation :
To test and refine control algorithms, considering factors such as speed regulation, load changes, and fault tolerance.

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Maintenance, Repair, and Operations (MRO) Technologies

Leveraging quantum-powered simulations can enhance the efficiency, accuracy, and speed of various aspects of aircraft maintenance. Here are some applications where quantum-powered simulations can substantially impact aerospace and defense.

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Quantum Algorithms for Aerospace Maintenance, Repair, and Operations (MRO)

Complex System Diagnostics to analyze vast amounts of sensor data from aircraft systems,

Image processing for surface defects detection using Quantum Algorithms.

Material Degradation Modelling for predicting wear and tear of components.

Scheduling and Resource Allocation

Optimized Repair Strategies

Fault Tolerance Analysis

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Digitalization and Advanced Manufacturing

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Simulations powered by Quantum Algorithms to enhance digitization & manufacturing

Additive Manufacturing :
Modeling complex thermal and fluid dynamics during the 3D printing of aerospace components for precision in additive manufacturing, leading to enhanced quality, reduced waste, and streamlined production.

Electromagnetic Compatibility (EMC) Simulations :
Assessing electromagnetic interactions within avionics systems to ensure compatibility and minimize interference.

Manufacturing Process Simulation :
Optimize manufacturing processes in aerospace, such as composite material layup, CNC machining, and sheet metal forming material usage, and improve overall production efficiency

Aeroacoustics Simulation :
To study and mitigate noise generated by aerospace systems, such as engines, airframes, and propellers. These are to reduce noise levels and meet regulator requirements.

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Complex Simulation applications for spacecraft innovation

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Powering Spacecraft innovation through simulations

Heat Shield Simulation :
Analyzing thermal response of heat-resistant materials in heat shields during atmospheric entry.

Thermal Vacuum Testing Simulation :
Simulating extreme thermal conditions encountered during space missions, including vacuum and temperature variations, to validate designs.

Designing More Efficient Rockets with CFD :

- Quantum computing in simulating complex fluid dynamics for design innovation.
- Highlights the behavior of propellants and combustion processes.
- Quantum simulations provide accurate and detailed insights.

Materials Design and Discovery :

- Quantum computing in materials design and discovery.
- Efficient exploration of vast materials databases.
- Prediction of properties for advanced and tailored materials.

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How is BosonQ Psi Transforming **Aerospace Simulation?**

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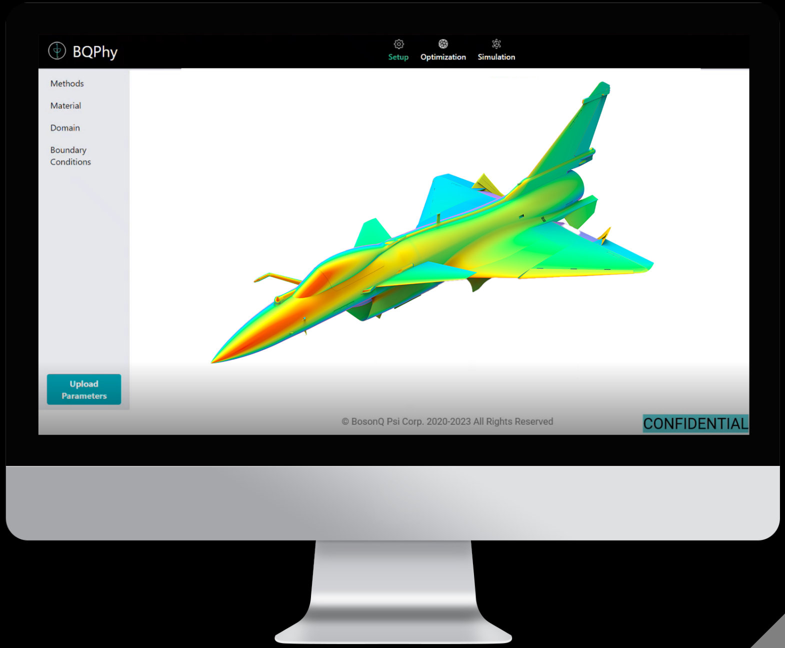
A Enables complex simulation with high accuracy in less time.

B Simulation experience is no different from traditional simulation software.

C No knowledge of Quantum computing is required.

D Seamless integration with Quantum hardware/ simulators over cloud.

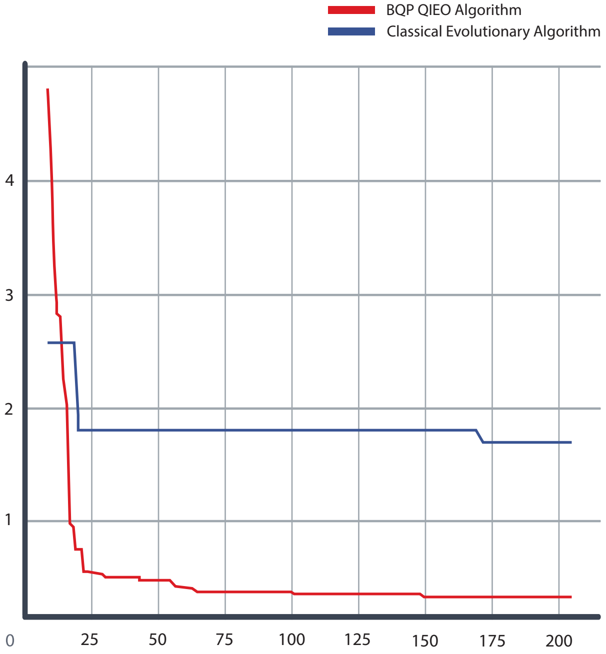
E Easily integrates with market-leading FEA solvers like Ansys, Siemens, and others.

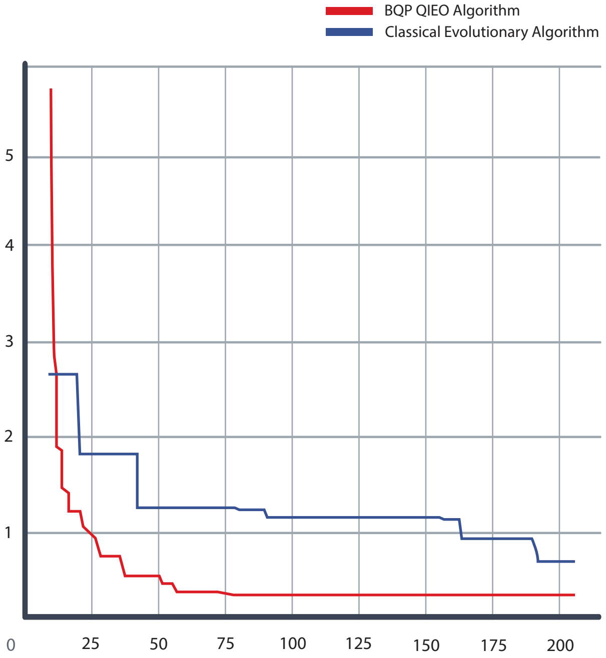


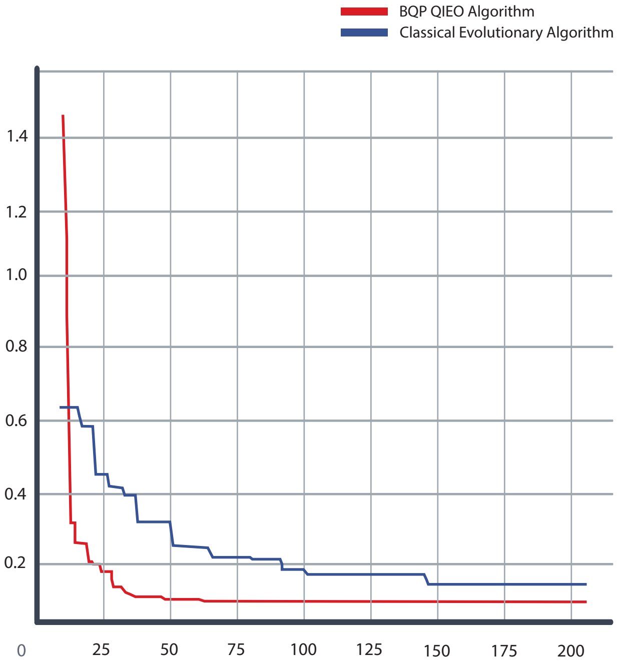
RESULTS

Capability: Quantum Inspired Design Optimization Solver (QIDO) by BQP uses Quantum Inspired Evolutionary Algorithm (QIEA) for efficient product designs.

Performance comparisons: QIDO converges faster than the classical approaches, requiring fewer computational resources. This is crucial for industrial applications like design optimization in the automotive and aerospace industries.



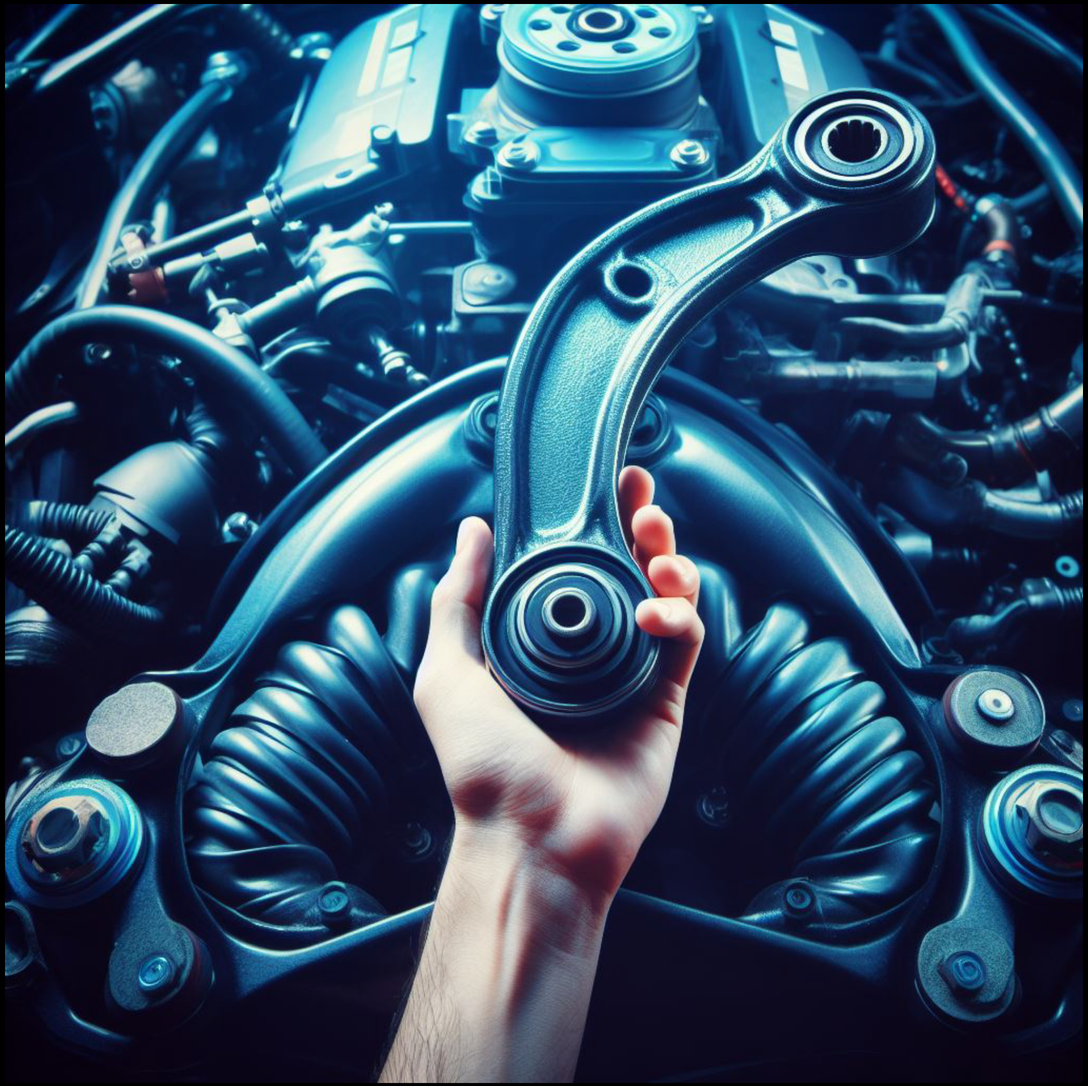




Topology Optimization

Control arms carry significant amount of weight and therefore it is essential to maintain the right balance between strength and weight.

BQP’s QIDO solver reduced control arm weight by 3.2x while maintaining strength, using 8x fewer computing resources compared to classical methods.



Airfoil cross-section (volume minimization):

Optimized airfoil: QIDO achieved a 60% weight reduction for an airfoil while meeting strength criteria, showcasing its efficiency and effectiveness in component optimization.

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Market Overview

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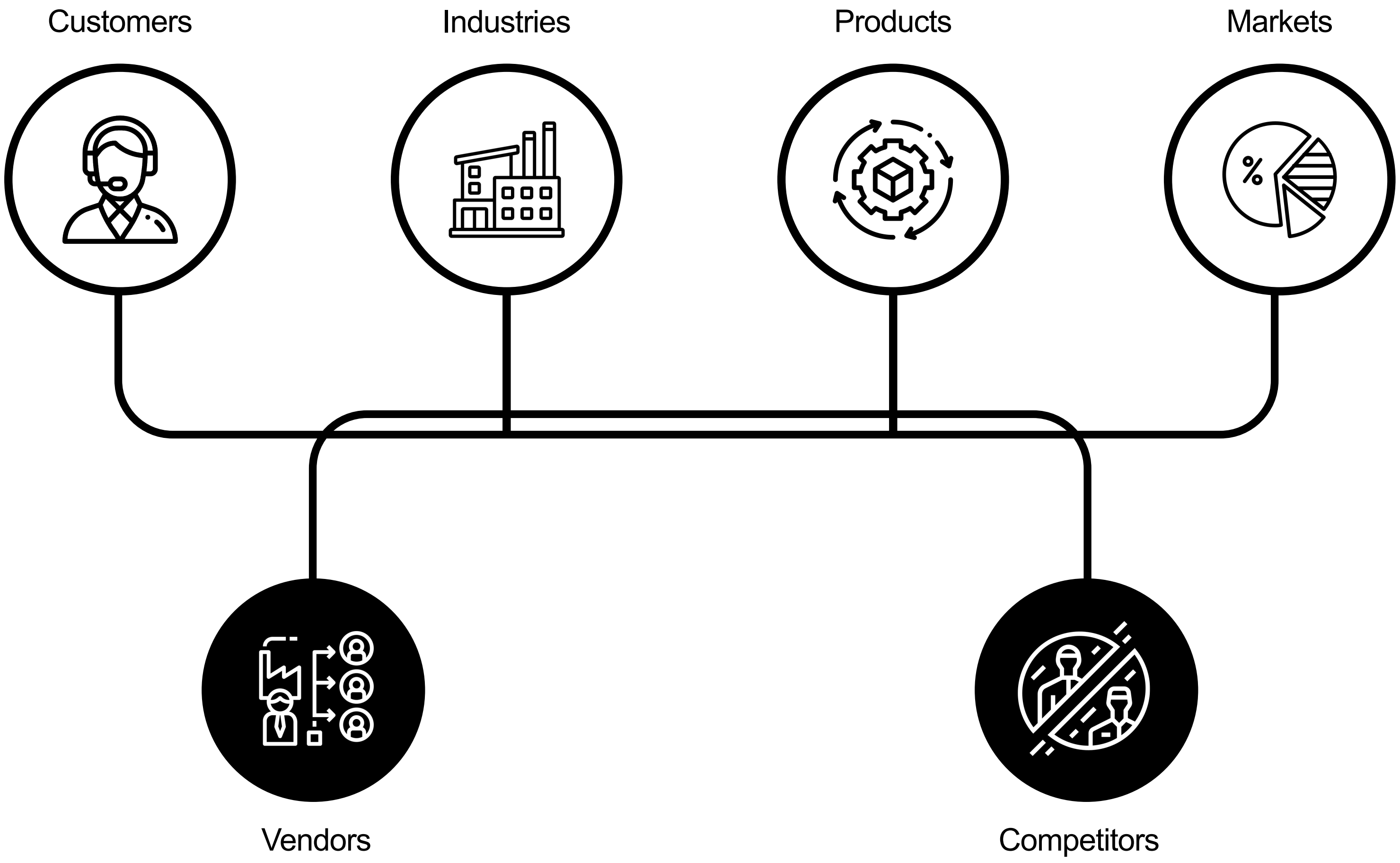
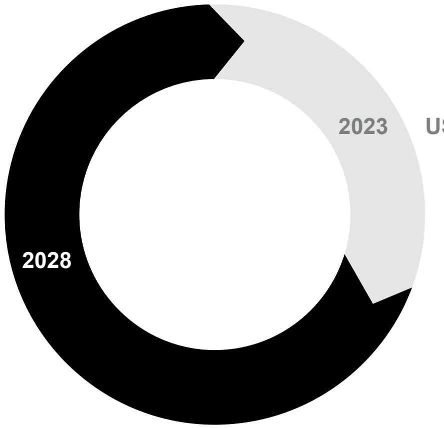
Market Overview : CAE Simulations



- The global CAE simulation market is projected to grow at a CAGR of 12% from 2023 to 2028.
- US is the largest market (33% market share), Asia-Pac is the fastest growing. The rising concerns about green-house gas emissions and the evolving battery technologies are anticipated to spur the North American regional market. Additionally, rapid penetration of IoT and increasing expenses for defense are a few factors influencing the North America regional market share
- Key markets for CAE simulations : U.S.; Canada; Mexico; U.K.; Germany; France; Italy; Spain; Russia; China; India; Japan; Singapore; South Korea; Brazil

Market Size in USD Billion

CARG 12.06%



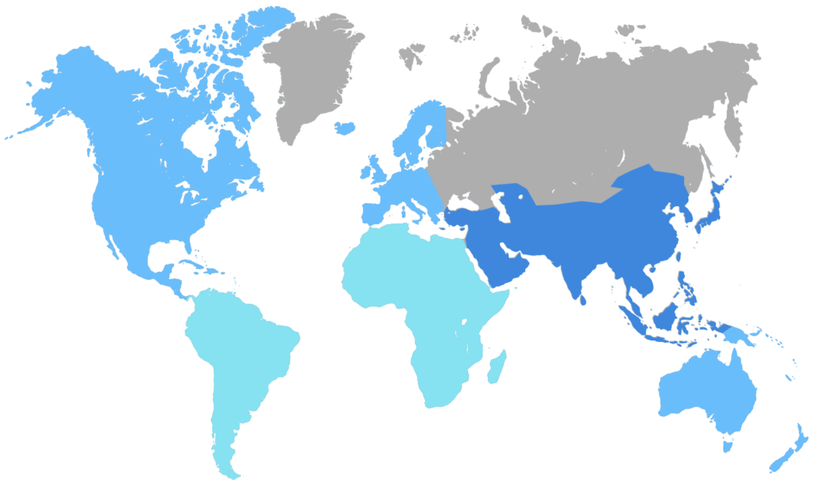
Simulation Software Market

Study Period	2018 - 2028
Market Size (2023)	USD 10.82 Billion
Market Size (2028)	USD 19.12 Billion
CAGR (2023 -2028)	12.06 %
Fastest Growing Market	Asia Pacific
Largest Market	North America

Major Players

Schneider Electric ALTAIR

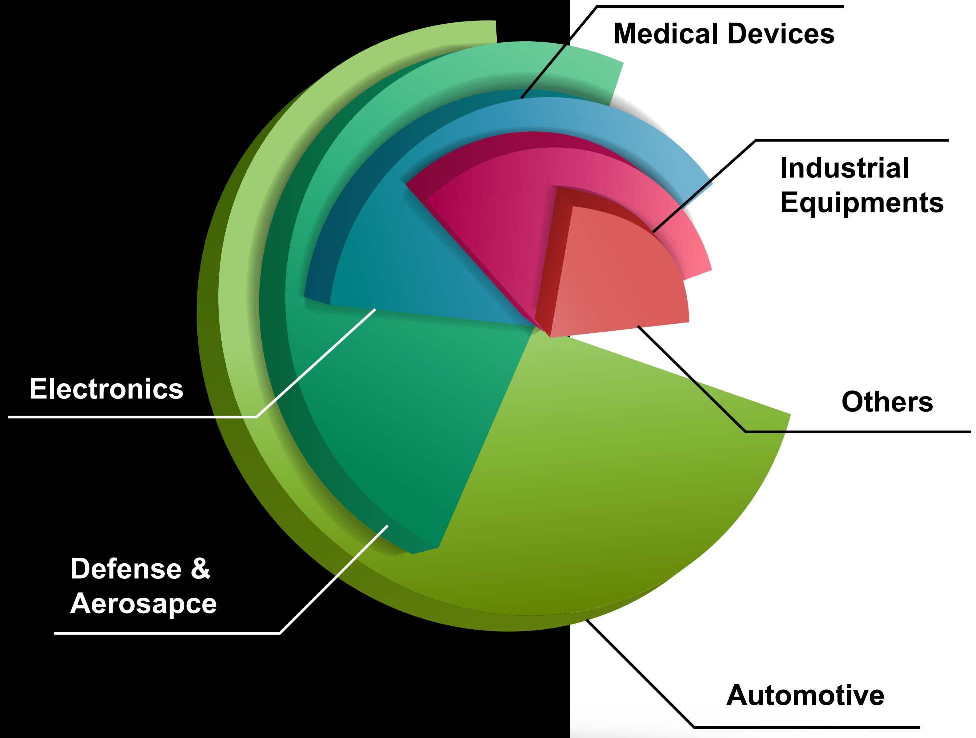
High Medium Low



Simulation Software - Growth rate by desiynMarket

In 2022, the Automotive, Aerospace & Defense industry held the largest market share around 50%

- The defense and aerospace end-use is expected to witness the highest growth rate over the forecast period, owing to the increasing use of CAE software.
- The medical imaging market is gaining traction in the market owing to its efficiency in diagnosing complex medical conditions.



The CAE simulation market has witnessed substantial growth over the past few years. Key growth trend is expected to continue in the future.

01

Adoption of Industry 4.0 to optimize manufacturing processes and enhance product performance, access to clouds and easy scalability of simulation solutions.

02

Integration of Artificial Intelligence (AI) and Machine Learning (ML) technologies with CAE simulation enabling faster and more accurate simulations to reduce time-to-market, and improve product quality.

03

Virtual Prototyping and Testing reduce the need for physical prototypes, minimize costs, and accelerate product development cycles.

04

Growing Demand from Automotive and Aerospace Industries: Major contributors to the growth of the CAE simulation market. The need for lightweight materials, fuel efficiency, and safety regulations drive the adoption of CAE simulation tools.

COMPONENT WISE BREAKDOWN OF SIMULATION MARKET

Based on software types, the industry is segmented into Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD), multi-body dynamics, and optimization & and simulation. In 2022, the FEA segment accounted for more than 51% of the market share and is anticipated to dominate the market over the forecast. FEA is a computational analysis methodology that helps determine a product's strength with respect to loading. FEA simulates real components to analyze problems in heat transfer, structural analysis, electromagnetic potential, and mass transport.

Computational fluid dynamics involves qualitative prediction of fluid flow using mathematical modeling and software tools. CFD is used to analyze the turbulence, flow, and pressure distribution of gases and liquids and their interaction with different structures. The industry players are aiming to develop application-specific software for customized process functions. Furthermore, multibody dynamic analysis has two types: Inverse and forward dynamics. Forward dynamics analysis is the movement of individual components by applying external forces. Inverse dynamics involves the analysis of forces to move the system in a specific way.

Current adopters of Quantum in Aerospace & Defense Industry

- Airbus partners with IonQ to develop quantum algorithms for aerospace optimization.
- Airbus Ventures invests in startups like Q-CTRL and QC Ware, seeking significant impact in quantum technology.
- Collaboration between IBM and Boeing for quantum simulations to study and mitigate corrosion processes in aerospace composites.
- IBM's Osprey QPU and classical systems are used for accurate quantum simulations, outperforming traditional methods like density functional theory (DFT).

- Survey of Quantum Technologies in Aerospace - NASA Technical Reports
- Engineering Quantum Computing for Aerospace and Defense - Boeing
- Quantum computing is not yet ready for aerospace, according to Airbus, Rolls-Royce and Lockheed Martin- ZDNet

Market Overview :
Quantum Computing

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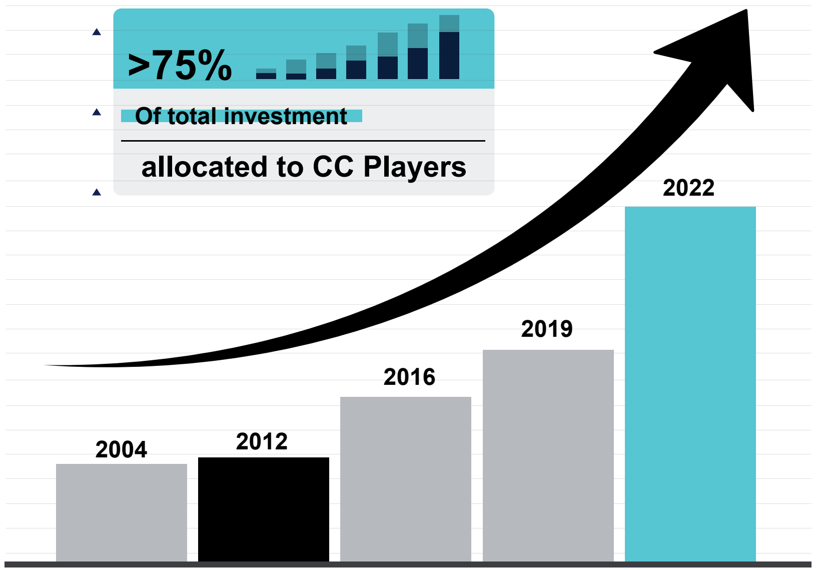
Investments in Quantum Technology reached their highest annual level in 2022 for early stage startups.

Volume of raised investment in the indicated year,' $ Million



2022 : $ 2.35 Billion

2021 : $ 2.23 Billion

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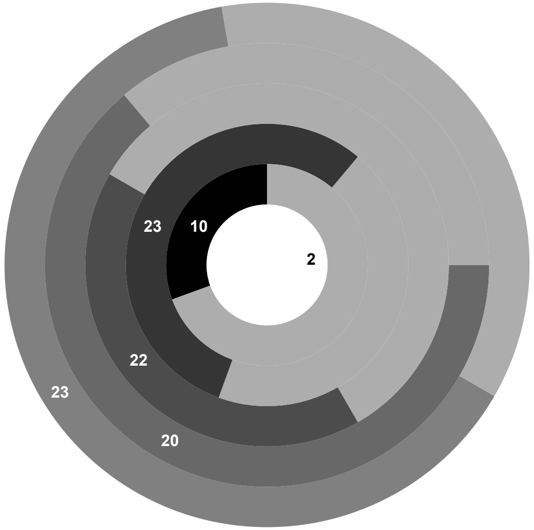
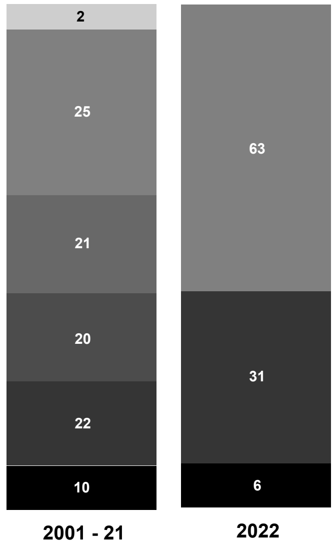
Split of venture capital investments, by deal type,
2001-22, % of total investment value

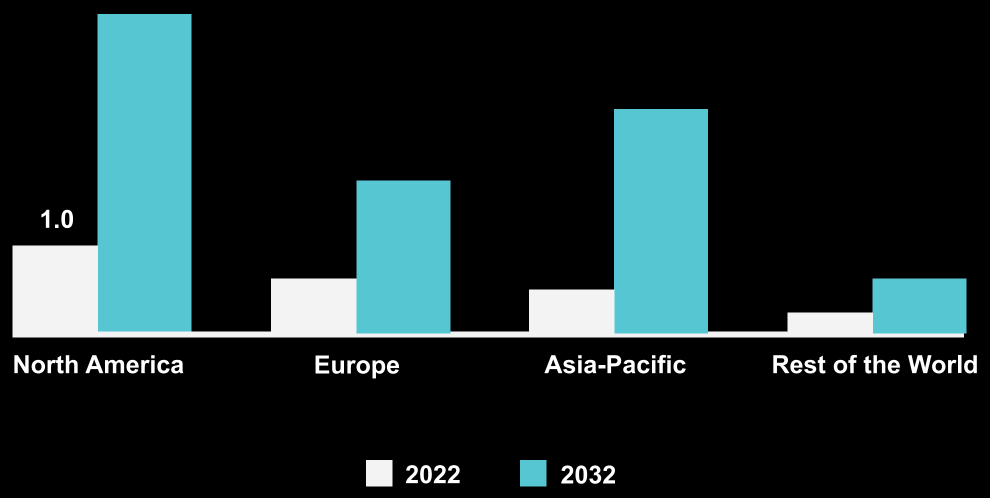


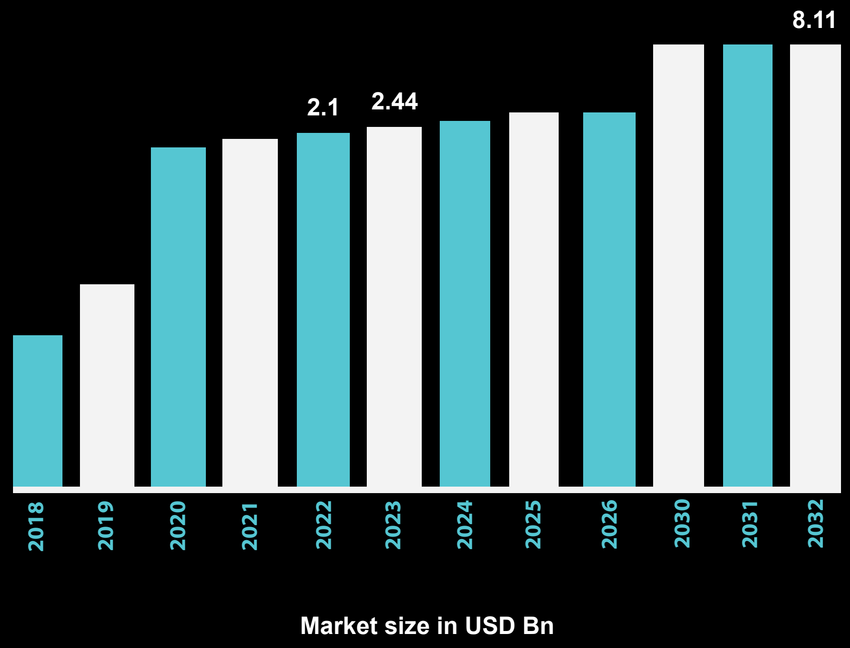
Split of investments, by deal type,
2001-21 vs 2022, % of total investment value



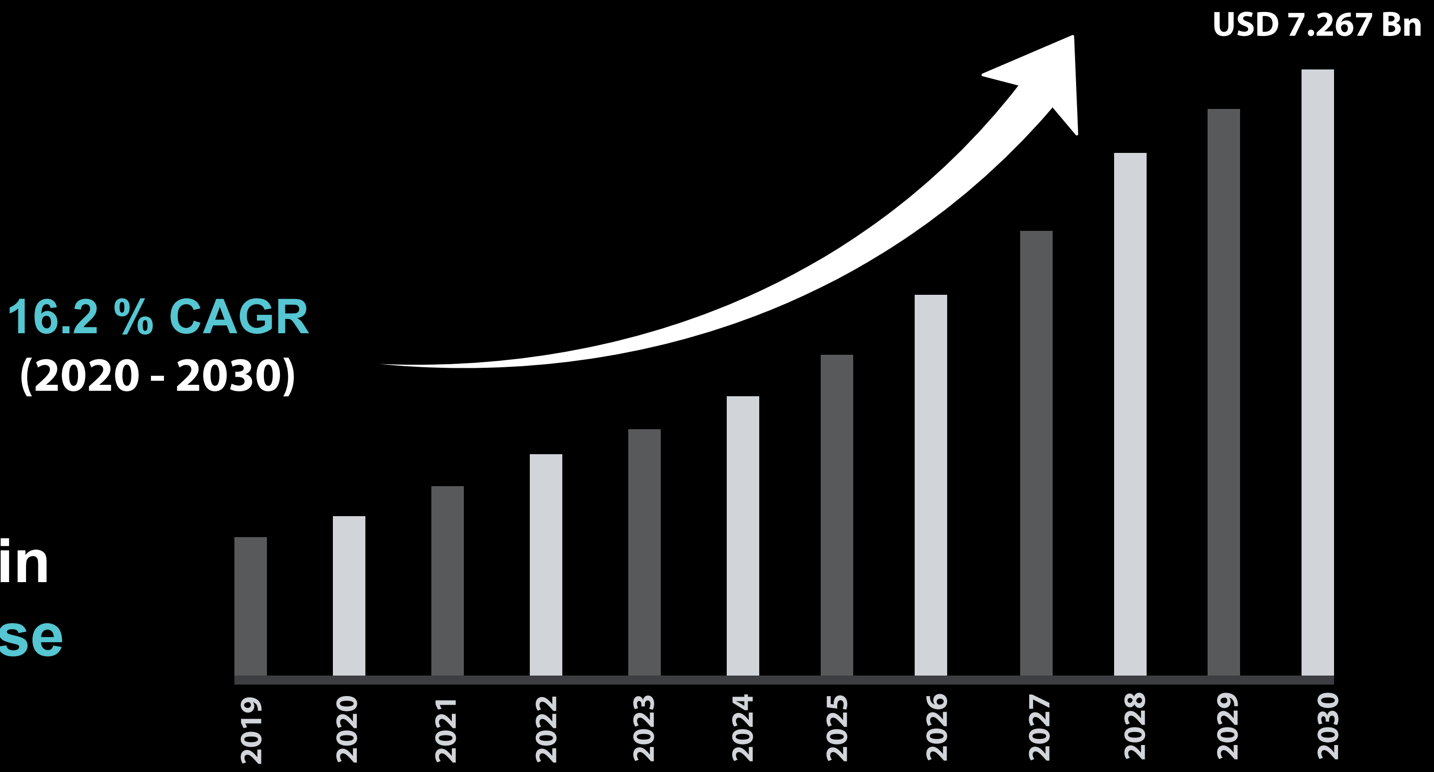
Most investment went to early-stage start-ups in 2022

Quantum Computing in
Aerospace and Defense Market

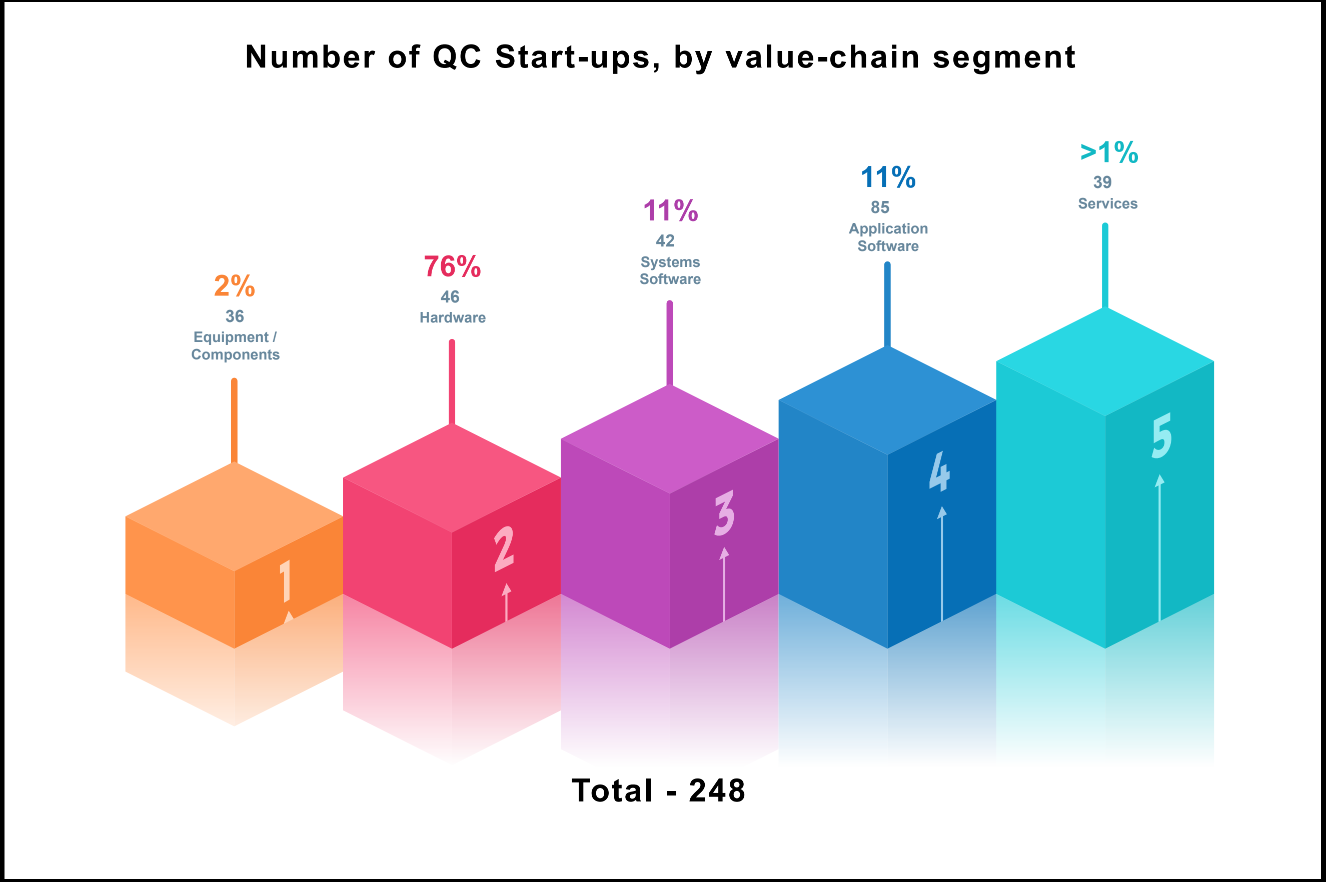




Quantum Computing in Aerospace and Defense



Among QC Value-Chain Start-Ups, Hardware Manufacturers Continue To See The Most Investments.



- The components segment is the only segment of the QC value chain that is generating significant revenue through sales to universities, research institutes, and technology companies.
- Players range from specialized QC players to general technology manufacturers (e.g., electronics), scattered across a range of technologies. Product maturity varies per component, yet nearly all components still require customization by quantum players.

In the near term, leveraging a hybrid operating system to distribute a complex problem between HPC and QC can bring a bigger computational advantage than either system alone.

Before a faulty-tolerant quantum computer is available, QC will likely speedup for three of the four types of problems for which it has demonstrated advantages.

01

Simulation Problems

QC is expected to enable precise simulation of molecules (e.g., electronic structure or molecular dynamics) compared to classical computations.

02

Optimization Problems

Optimization algorithms aim to minimize the cost function based on multiple parameters.

Classical algorithms are advantageous in selecting bigger problems and turning them into digestible smaller problems, which quantum algorithms can calculate faster.

03

Hybrid ML/AI Problems

Quantum algorithms can reduce the training time for ML/AI models, especially in the most computationally intensive layers, by providing at least a polynomial speedup in learning certain data classes.

04

Cryptography Problems

By breaking classical encryption protocols, quantum algorithms can be dangerous to services, including online/mobile communication and bank transfers. Quantum technology can provide new encryption protocols with enhanced security.

BosonQ Psi

OUR MISSION

To serve customers and achieve faster time to market while making their products safer and more sustainable.

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Thank You!

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