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A Quantum Leap for Automotive Simulations

GET THE COMPETITIVE EDGE WITH ACCELERATED, EFFICIENT SIMULATIONS.

WHITEPAPER

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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 0 and 1 at the same time.		Calculates with transistors, which can represent either 0 and 1.
Power increases exponentially in proportion to the number of qubits.		Power increases in a 1:1 relationship with the number of transistors.
Well Suited tasks like optimization problems, data anlysis, and simulations.		Classical computers best handle most everyday processing.

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

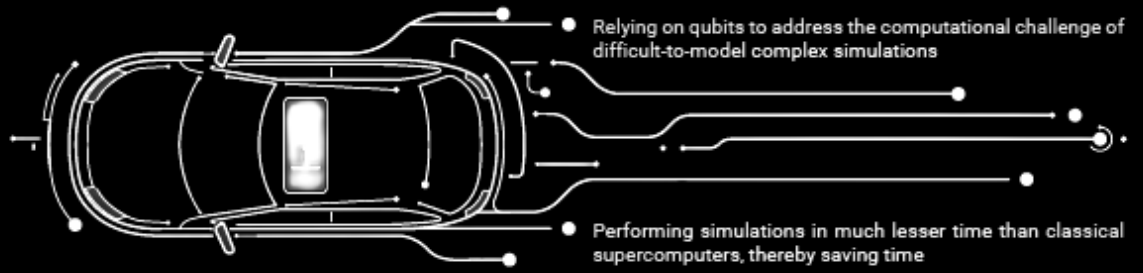
Quantum algorithms based on principles of Quantum significantly accelerates complex problem-solving, like optimization and swap tasks, traditionally demanding for classical systems.

Solving Complex Simulations Faster

Design engineers can now experience quantum benefits with existing computing platforms

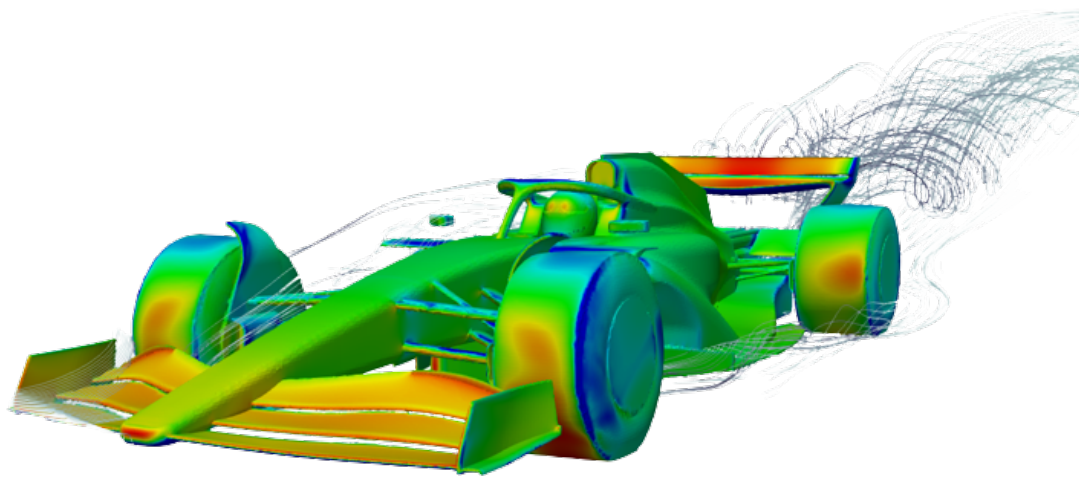
Here's how:

- Lower runtime costs for highly complex simulations
- Faster convergence times.
- Significantly fewer compute resources per optimization iteration than classic gradient methods.
- Reach global minima in fewer iterations
- Superior optimization outcomes, reaching global minima instead of local



Overview : Quantum Computing For Engineering Simulations

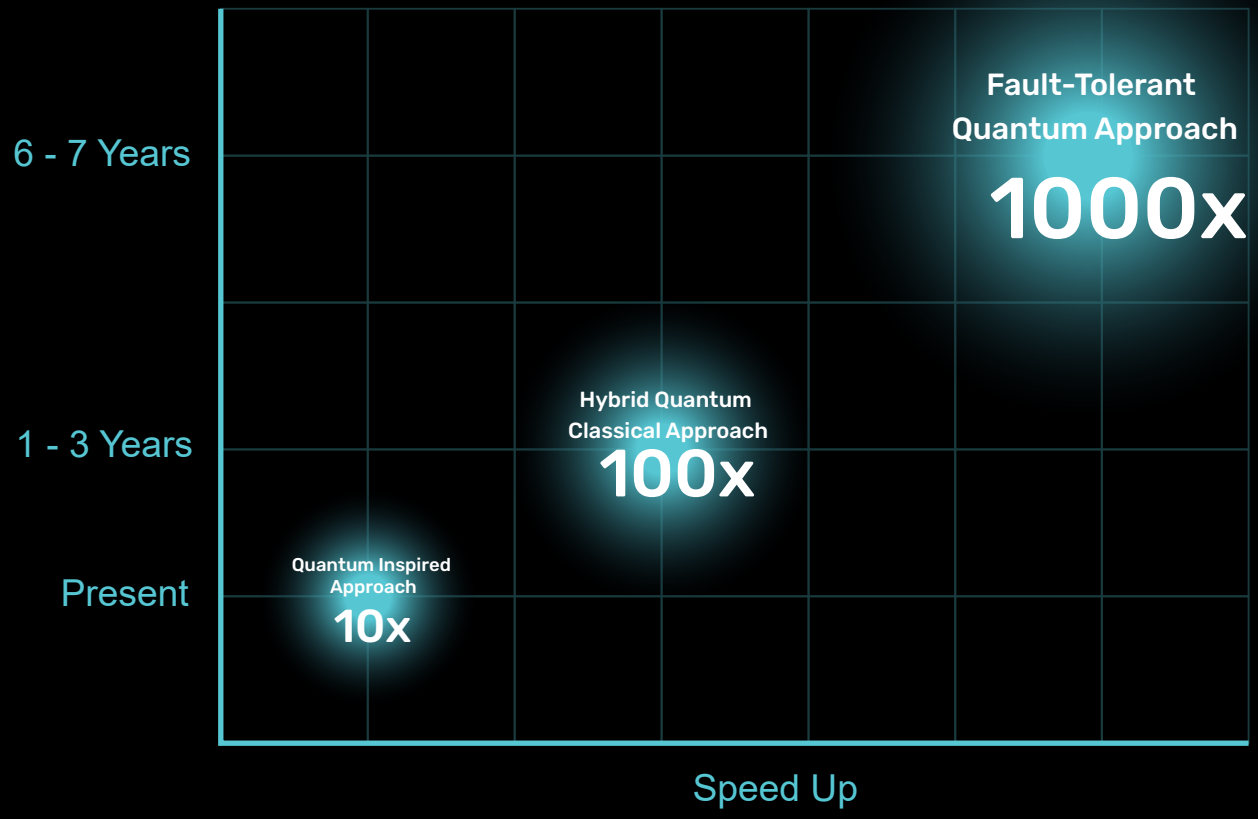
- Large-scale fault-tolerant quantum computing has yet to mature fully.
- Development of Hybrid Quantum Classical (HQC) algorithms that use classical processing is still in progress.
- Quantum-inspired algorithms, which use classical algorithms to imitate the fundamental quantum phenomena to enhance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



The automotive 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 today

Expect 1000x results as Quantum Matures

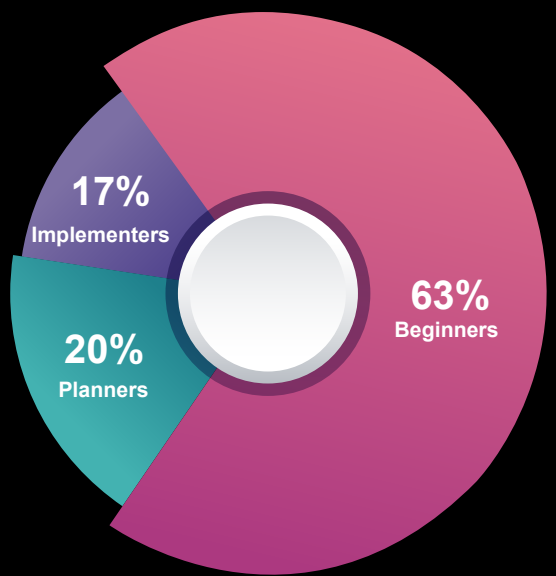


Current State of Quantum Adoption by Automotive Industry

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.

- Telecom and Public Sector — 50%
- Aerospace and Automotive — 36%
- Life Sciences — 30%
- Energy and Chemicals — 24%
- Banking and Insurance — 22%



- 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, NEC

Superconducting Gate Quantum Computing

IBM, rigetti, Google, amazon, FUJITSU, IQM, OQC, ILMANJARO

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, Google

CLASSICAL SYSTEMS

Simulated Quantum Computing

IBM, amazon, Microsoft, Atos, NVIDIA

Quantum Inspired Computing

FUJITSU, Microsoft

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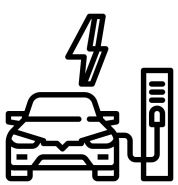
Megatrends In The Evolving **Automotive Industry**

Key Trends Increasing Vehicle Design Complexity

- Electrification
- Connected Vehicles
- ADAS & Safety

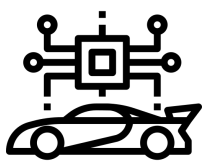


Electric Vehicles

The consumer shift to EVs has significantly focused on enhancing critical components, such as batteries, aerodynamics, power trains, and vehicle dynamics.

Connected Vehicles

To enable a seamless driving experience, manufacturers are developing electronics/Electrical (E/E) architectures, improved data handling, and Connectivity to pay-on-the-go services.



ADAS

Better sensor fusion, high-performance processors, AI, and Machine learning are being integrated into assisted driving systems.

Megatrends : A timeline of Rising Vehicle Complexity

Immediate (0 - 3 Years)	Near Future (3 - 5 Years)	Long-Term Future (5 - 10 Years)	Far Future (10+ Years)
Increase in electric vehicle models and charging infrastructure	Robust battery technology with alternate fuels like Hydrogen.	Non Lithium batteries go mainstream with regenerative systems.	Energy - neutral vehicles, ban on fossil fuels.
Ride - Sharing and 0 micro - mobility sharing.	Autonomous ride - sharing fleets.	Mobility as a service with public transit, robotaxis.	Aerisl Mobility Services such as VTOLs
In - Car infotainment & Connectivity.	Collision avoidance systems, L3 - L6 ADAS	Seamless vehicle to vehicle communication and data exchange	AI - Enabled accident congestion free transport.
Reduced carbon footprint.	Integration of circular economy principles in design, charging with renewable sources.	Zero - waste vehicle manufacturing and end of life recycling.	Carbon - negative production and operation.

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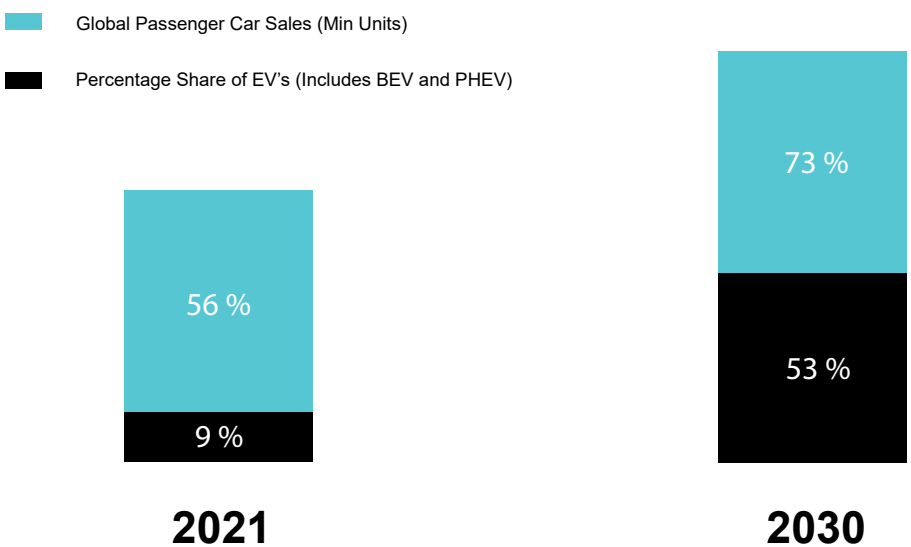
Electric Vehicle Sales : Passenger Cars

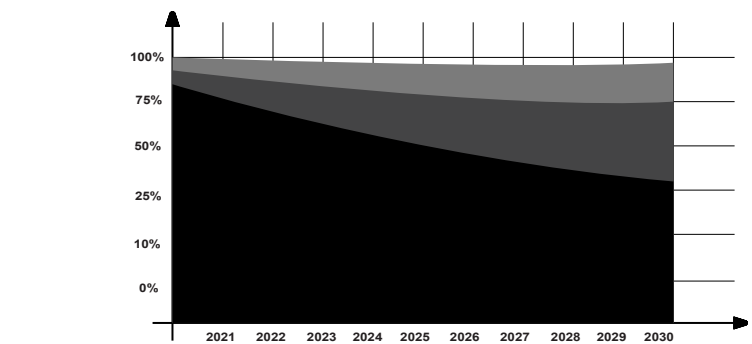
Battery Electric Vehicles (BEVs) will gain a significant market share of internal combustion engines (ICEs) by 2030

Market share of EVs in Passenger car sales for 2021 and 2030

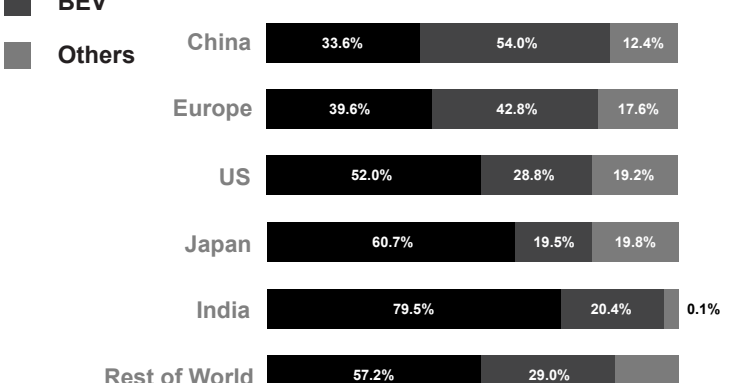


CAGR (2021 - 2030)	Global Passenger Car Sales	Global Electric Car Sales
	3%	25%

Market share by powertrain from 2021 to 2030



Market share by powertrain by country for 2030



Electric Vehicle Battery : Investment Priorities

With battery technology and capacity at the forefront, the stakeholders are investing heavily to match consumer expectations and achieve scalability.

Industry's top investment priorities in the EV ecosystem

1 Battery

- Battery has seen the highest growth in terms of investments.
- The pursuit for the optimal design to enhance the energy density of an EV battery pack is still underway.
- Battery materials, safety, and life are other major concerns.

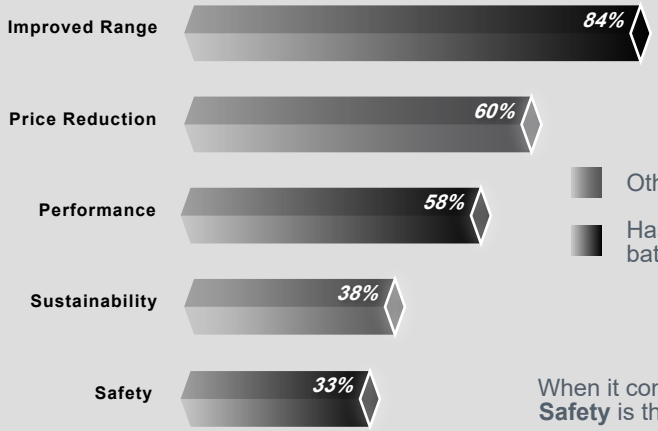
2 Fast Charging

- Fast charging has been the second-highest priority for investments.
- Industry experts believe that fast charging would expedite the adoption rate of EV's among consumers.

3 Software

- The third-largest investment priority for EV development is software.
- Battery and thermal management systems are major focus areas under the software.

Focus areas of industry stakeholders for EV's



When it comes to investments, **Safety** is the industry's **lowest priority.**

Commercialization timeline of key battery technologies

2025	Ultrafast Charging
2027	Solid State Batteries
2030	900Wh/L energy density batteries
Beyond 2030	Wireless Charging

Upcoming High Capacity and energy density batteries pose more risk of overheating and catching fire.

Risk Assessment and Impact of Battery Heating

Given the current stage of market adoption and investment priorities to increase the battery size. It is inappropriate to assert that EVs are safer than ICE vehicles since many cases of battery overheating and fires have been reported.

United States: Risk Assessment of catching fires for ICE and BEV (2020)

Fuel Technology	Market share by sales (2020)	Battery fires per million vehicles	Risk of catching fire (%)	Amount of water needed to put out a fire	Total recall due to fire risk in 2020 (approx.)	Cost of recall per vehicle
ICE (Gasoline)	90%	15,290	1.53%	1,000 gal	1 Mn	up to USD 1000
BEV	3%	250	0.03%	40,000 gal	150,000	up to USD 11,000

Compared to ICE vehicles, recalls of electric vehicles are far more expensive

01 Ford

In 2022, Ford recalled 49,000 Mustang Mach-E over high-voltage battery defect.

Battery overheating was the primary concern for the OEM.

The OEM halted the deliveries of Mach-E following the concerns.

02 Hyundai

In 2023, Hyundai announced to recall of 82,000 kona EV after receiving reports of several fire cases.

Nearly half of the OEM's 2020 profit was lost due to this recall.

03 General Motors

In 2021, GM started recalling chevrolet Bolt's EV's due to a faulty battery.

As of 2022, a total of 140,000 EV's have been recalled.

It is estimated to cost around USD 2Bn.

- EV fire accidents have started to emerge and are growin: For instance, in London, there were 32 and 102 fire incidents in 2020 and 2021, respectively.
- Since fire extinguishing is a difficult task, sustainability is questionable: It takes around 40x more water than ICE vehicles and over 24 hours to extinguish the EV fire.
- Even solid-state batteries are not entirely safer: Solid-state batteries may fail due to high pressure resulting in a reaction between internal oxygen and electrolyte.

Solving thermal runway with Simulations powered by Quantum Algorithms

Thermal Runway Problems Leading to EV Accidents can be solved by rigorous coupled simulations powered by Quantum Algorithms.

Analyzing battery behavior under varying temperatures, loads, and charging rates.

Determining optimal design parameters, including the ideal cooling rate, heatsink materials, fans, and cooling channels.

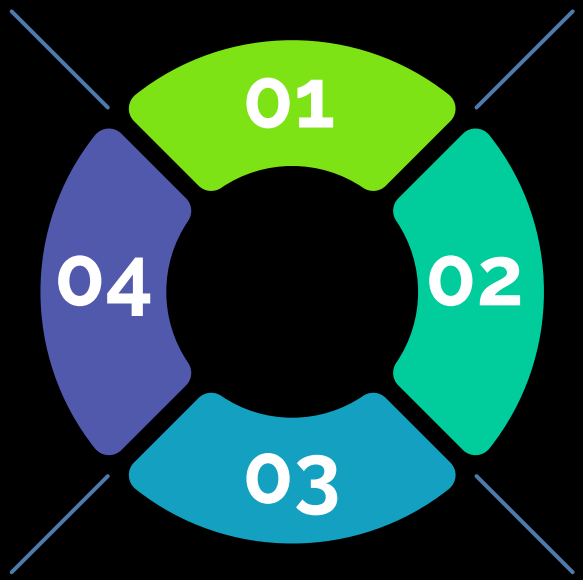
Identifying the crirical components that generate heat during charging and discharging cycles.

Designing an efficient BMS for extended battery life, improved safety, and optimized performance.

Building efficient power trains with Simulations powered by Quantum Algorithms

The only viable approach to achieving a balance between performance, fuel efficiency, and environment objectives in a single package is to simulate powertrain design. Through powertrain modeling, the manufacturer can -

Evaluate various vehicle performance parameters and drive cycles.

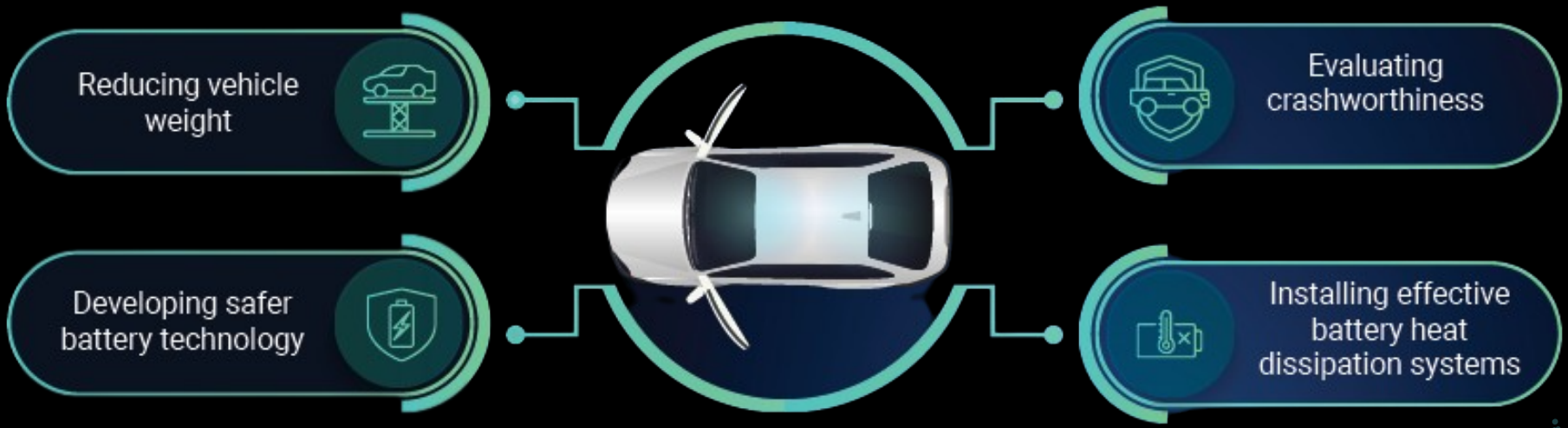


Optimize the nominal and peak torque, current, RPM, and operating points at different loads.

Optimize speeds, power, efficiency, and regeneration energy possibilities for the motor.

Establish synergy between the battery and traction motor.

Enhancing Vehicle safety with Simulations powered by Quantum Algorithms



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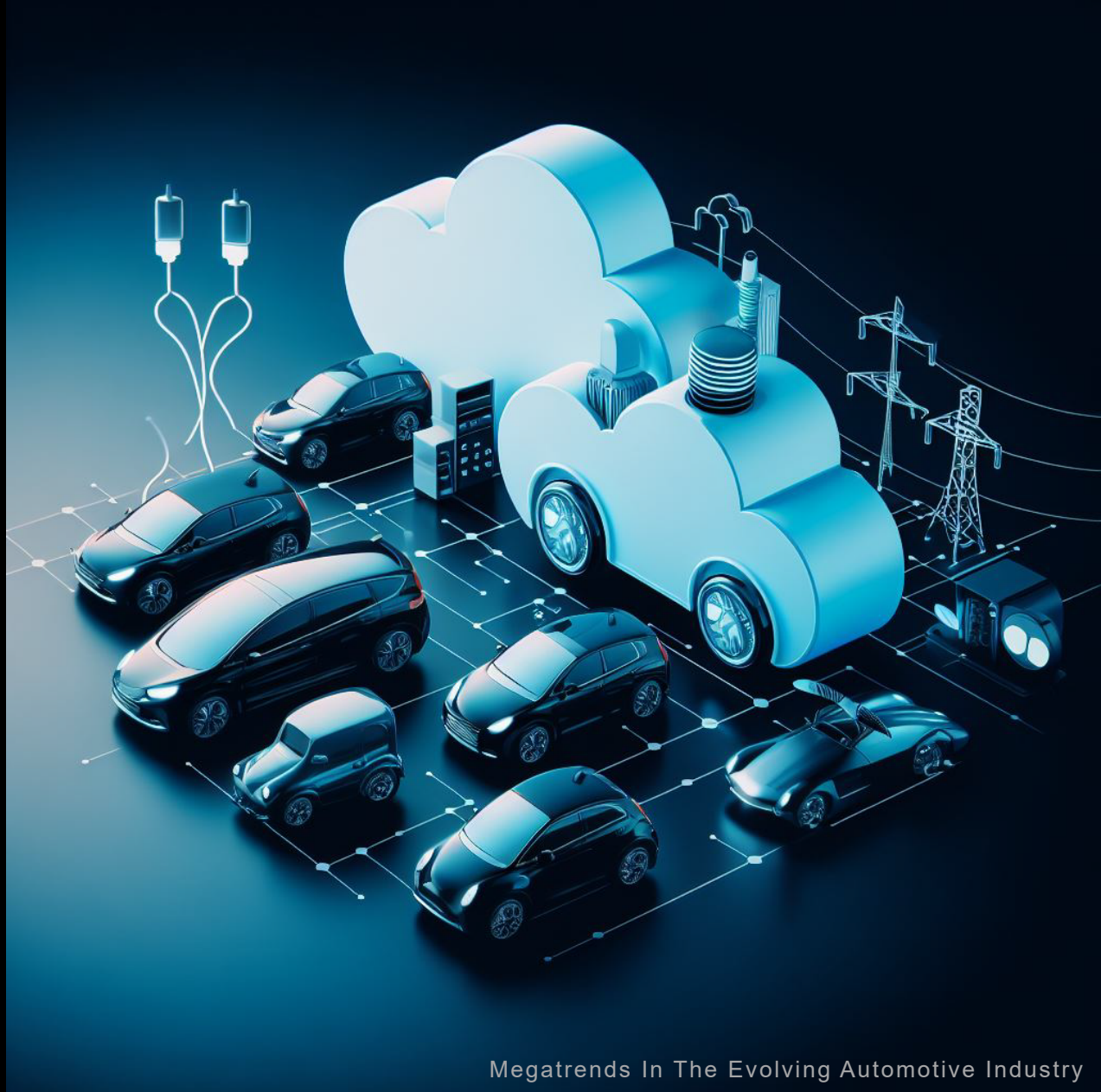
Connected Vehicles

Connectivity is emerging as a standard feature in vehicles as it offers an engaging digital experience to the driver and passengers. According to Juniper Research, the number of connected vehicles on the road will reach 192 million in 2023 and will grow two-fold in the next five years.



Simulations possible with quantum algorithms can enhance development of future-connected vehicles.

Achieving effective deployment of connected vehicles requires high-accuracy multivariable simulations that can accurately assess and implement control strategies for various operations, including vehicle-to-vehicle, vehicle-to-infra and vehicle-to-human.

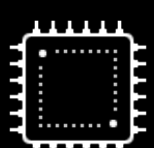
Digital Cockpit

Integration of sophisticated hardware and software

Designing a user-friendly and scalable Dashboard

Driving Scenarios

Accurate replication of real-world driving scenarios



Requires powerful hardware

Digital Twin

Real-time processing of a large amount of data

Requires high-quality and high-frequency data

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ADAS & Safety

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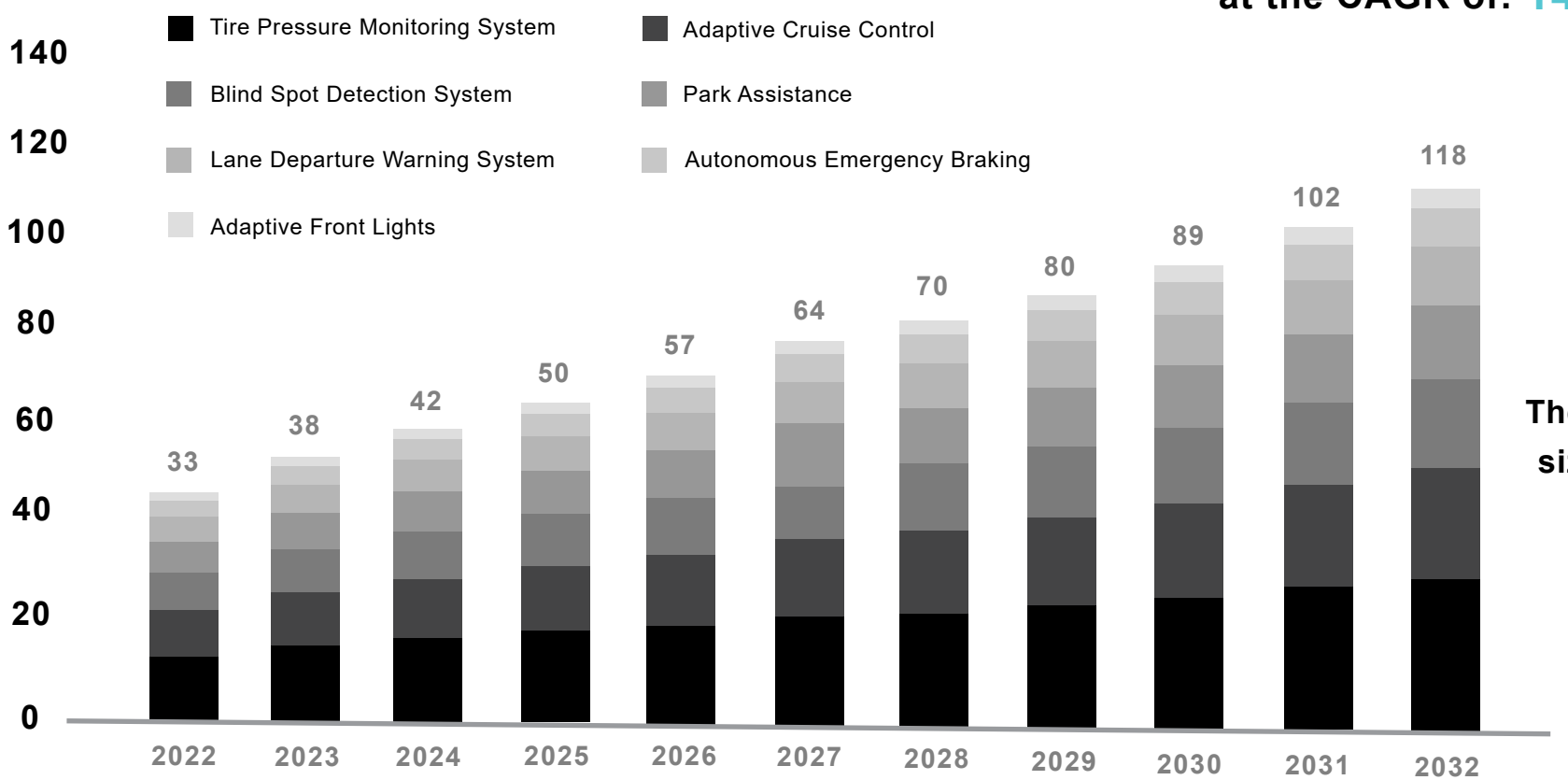
Global ADAS Market

Size, by Solution, 2022 - 2032 (USD Billion)

The Market will Grow at the CAGR of: 14%



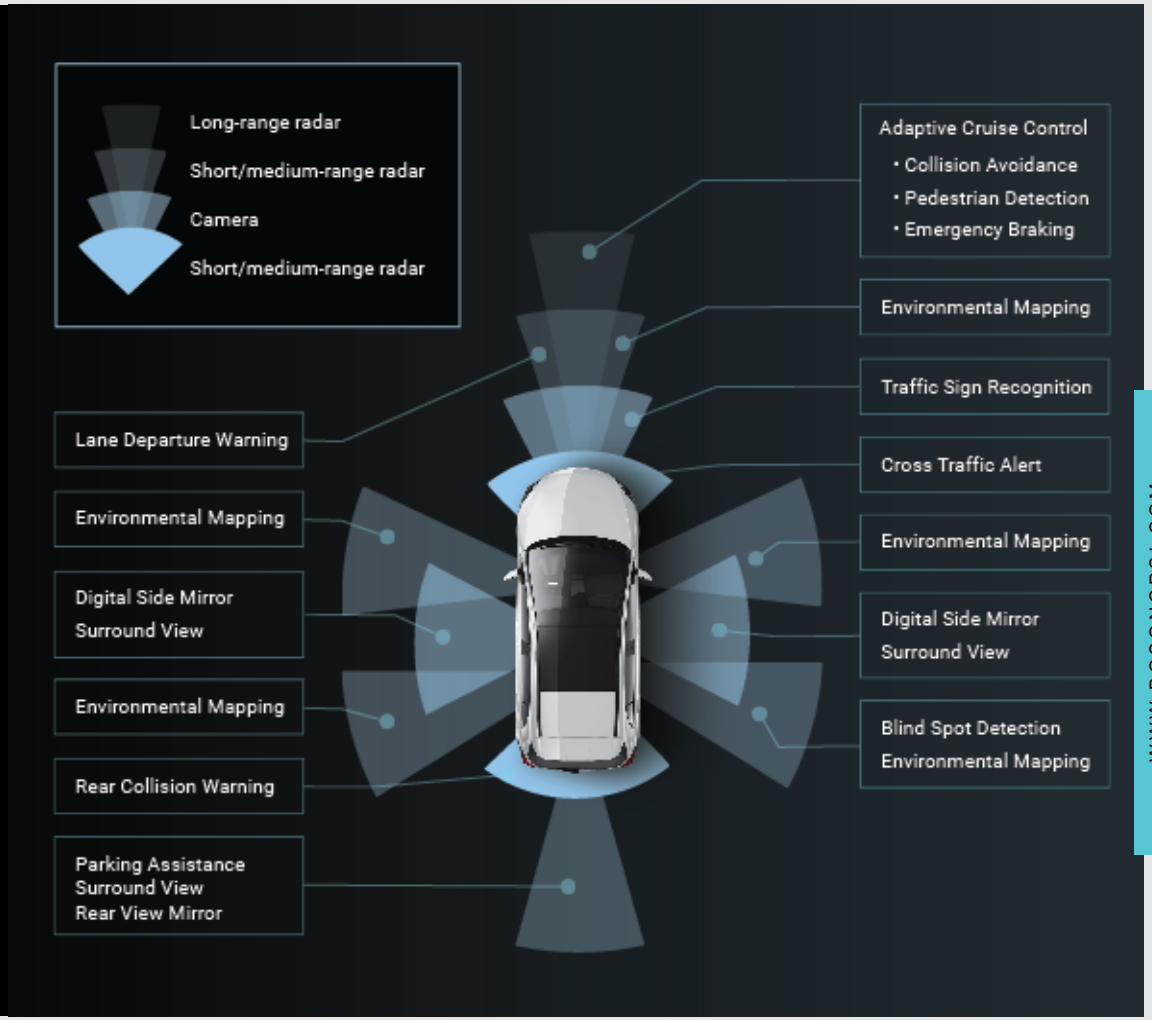
The forecasted market size for 2032 in USD:

$118B

Role Simulations for Designing robust ADAS systems.

Faster Simulations allow engineers to recreate a wide range of driving scenarios, including different road conditions, weather conditions, and traffic situations for designing better Assisted Driving and Safety (ADAS Systems).

These scenarios are typically not possible with the traditional approach to simulation.



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How is BosonQ Psi Transforming **Automotive 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

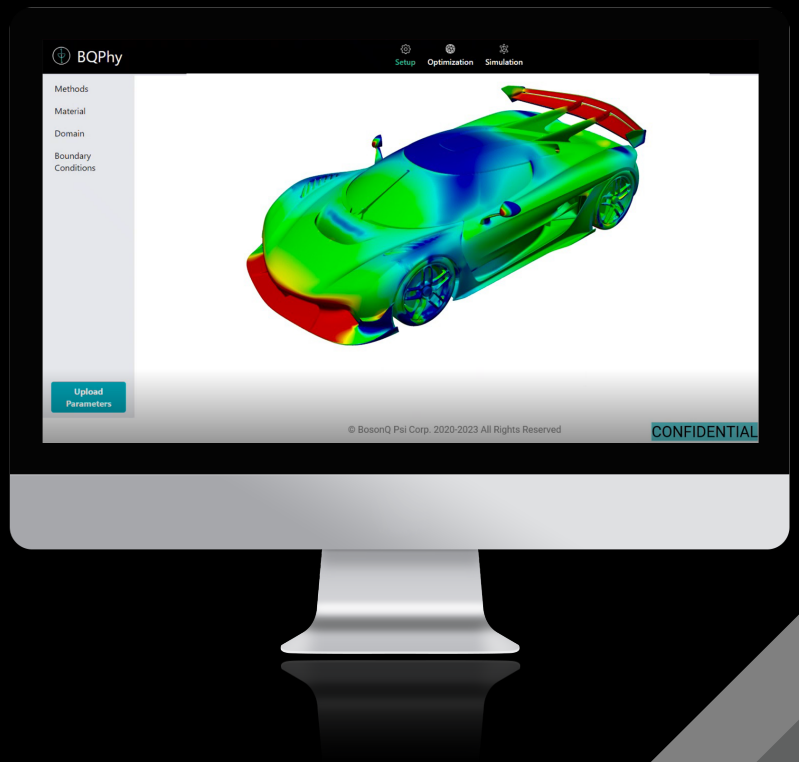
No knowledge of Quantum computing required.

D

Seamless integration with Quantum hardware/ simulators over cloud.

E

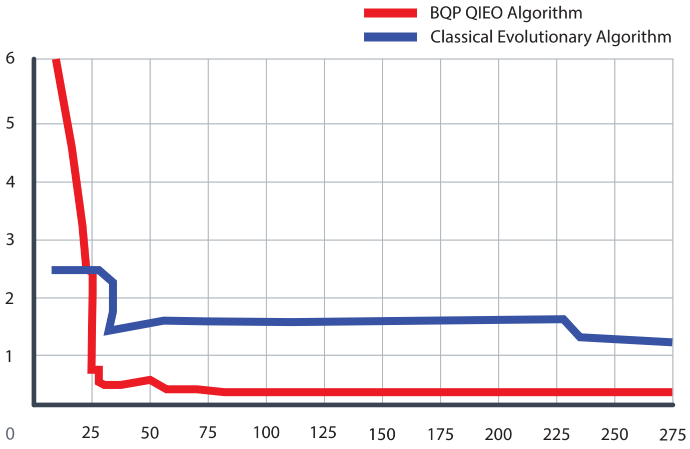
Easily integrates with market-leading FEA solvers like Ansys, Siemens, and others.

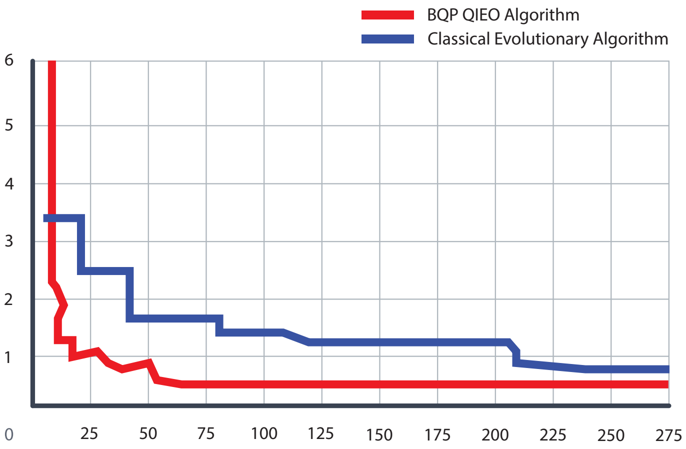


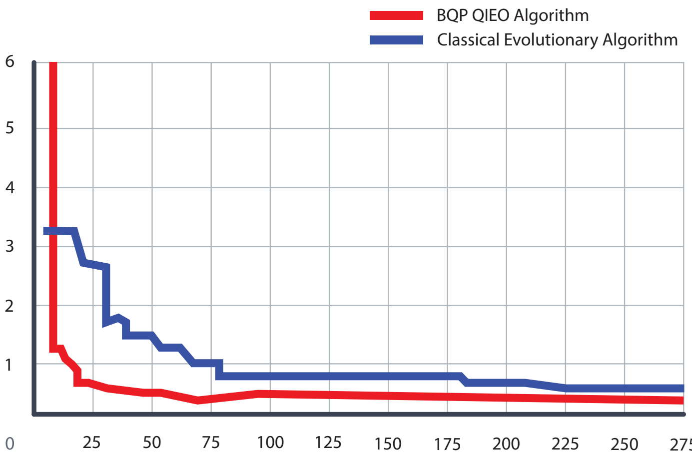
RESULTS

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

Performance comparisons: QIEA (QIDO) converges faster than gradient-based and simulated annealing approaches, requiring fewer computational resources. This is crucial for industrial applications like Topology Optimization & Design Optimization in automotive and aerospace industries.



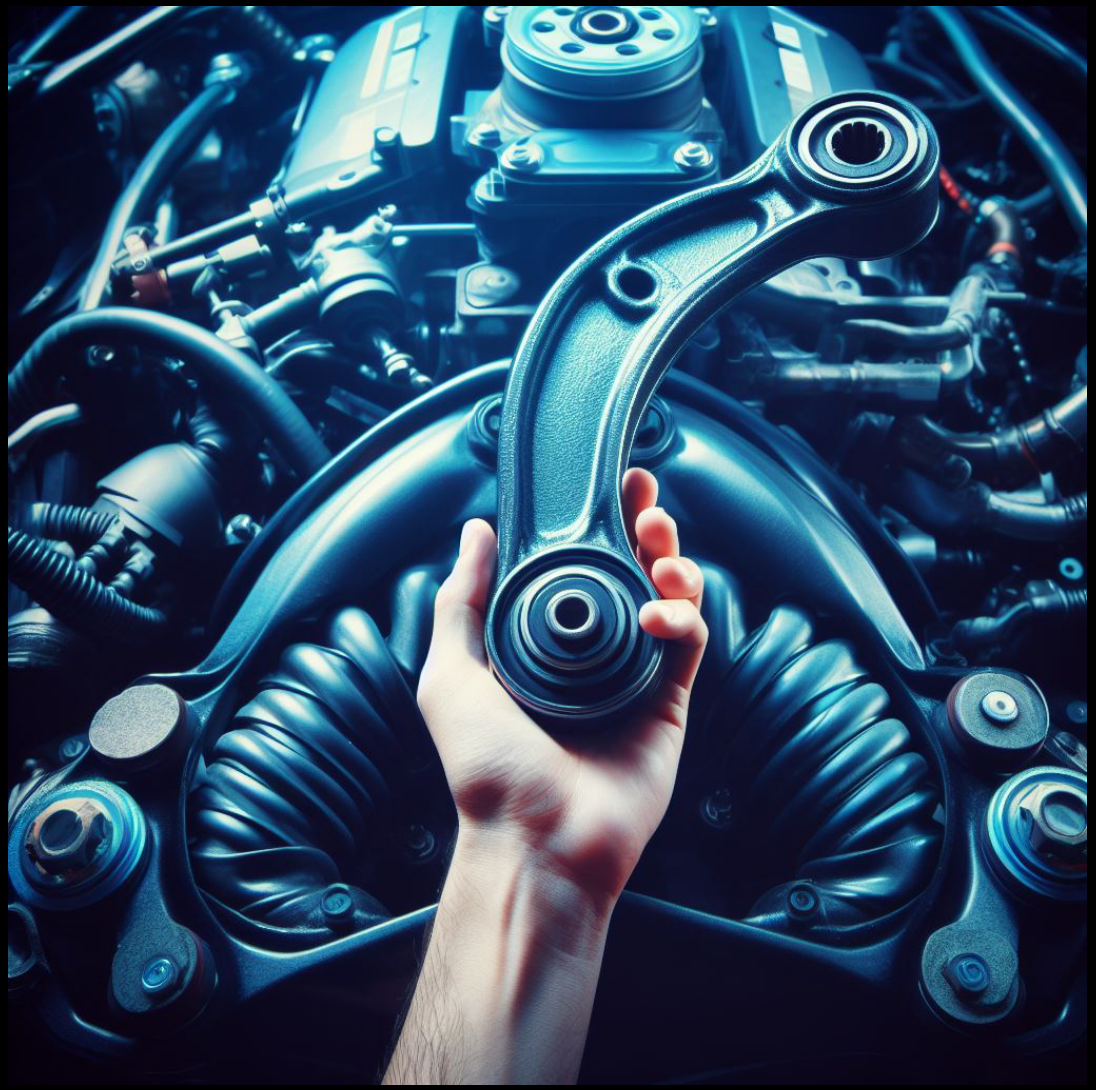




Topology Optimization of Control Arm

Control arms carry significant amounts of weight connecting wheels with the Chassy is essential to maintain the right balance between strength and weight of the car structure.

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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OUR MISSION

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

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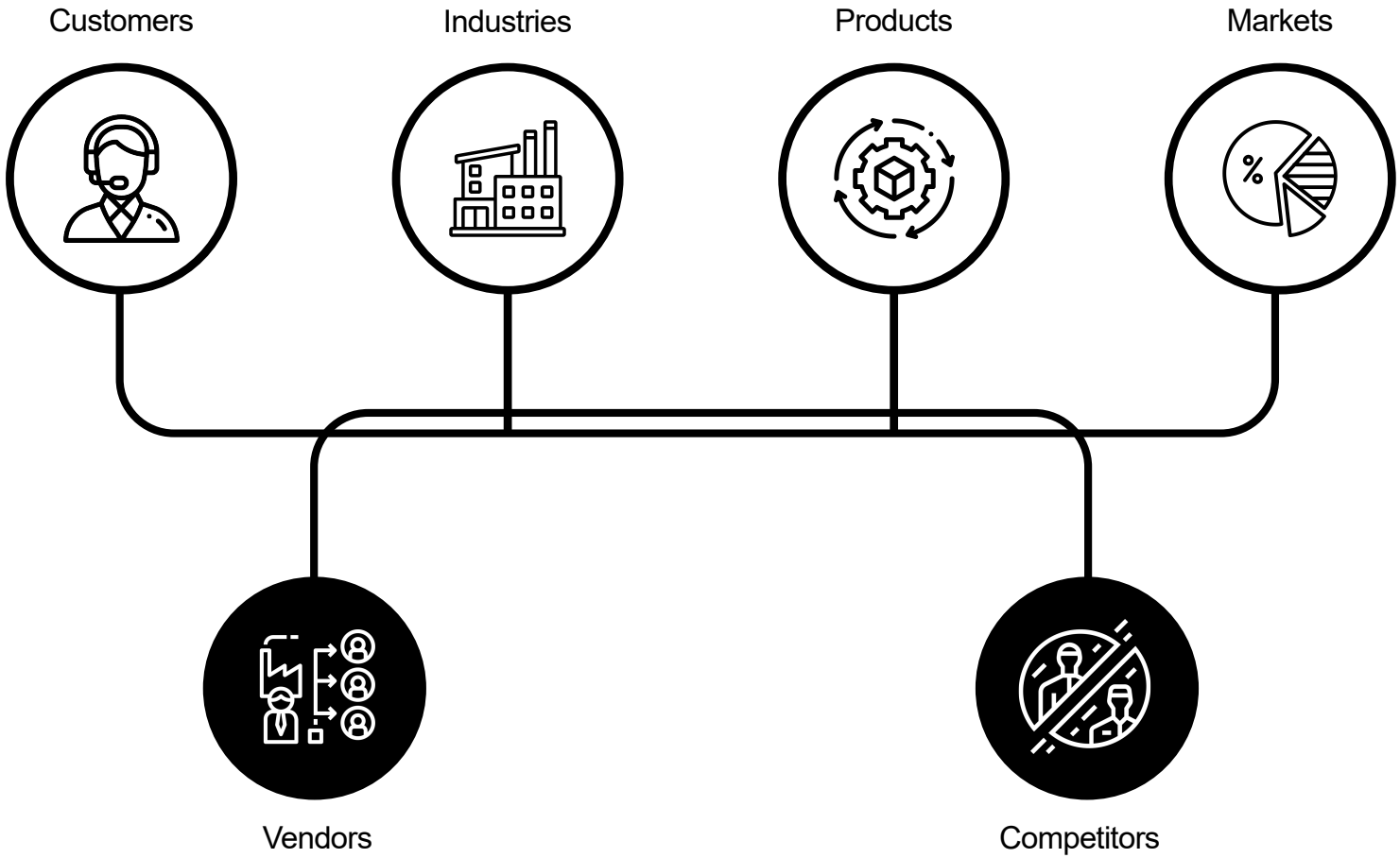
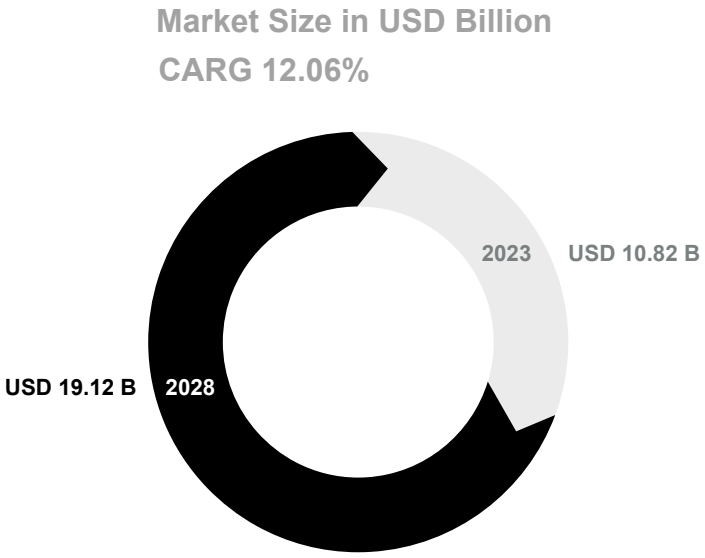
Market Overview

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**

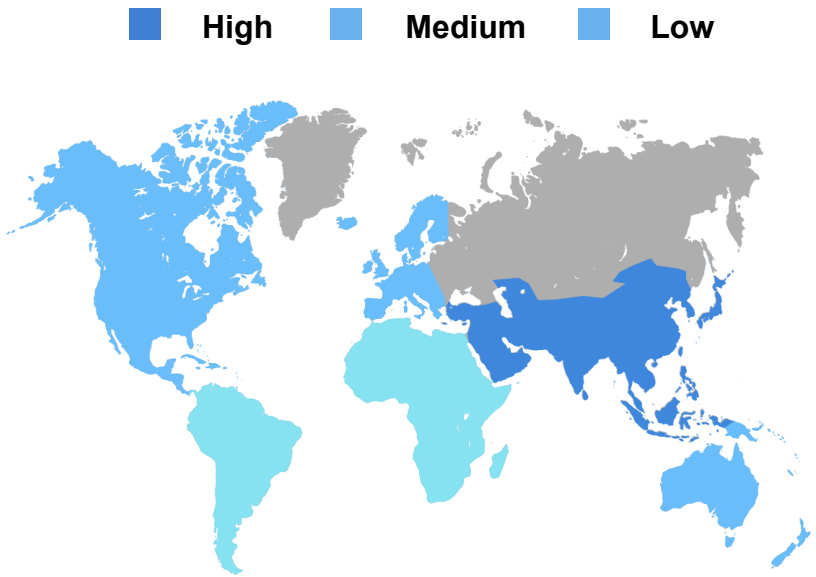


Study Period	2018 - 2028
Market Size (2023)	USD 10.82 Billion
Market Size (2028)	USD 19.12 Billion
CAGR (2023 -2028)	12.06 %
Fastest Growing Market	Asia Pacific
Largest Market	North America

Major Players

Schneider Electric

ALTAIR

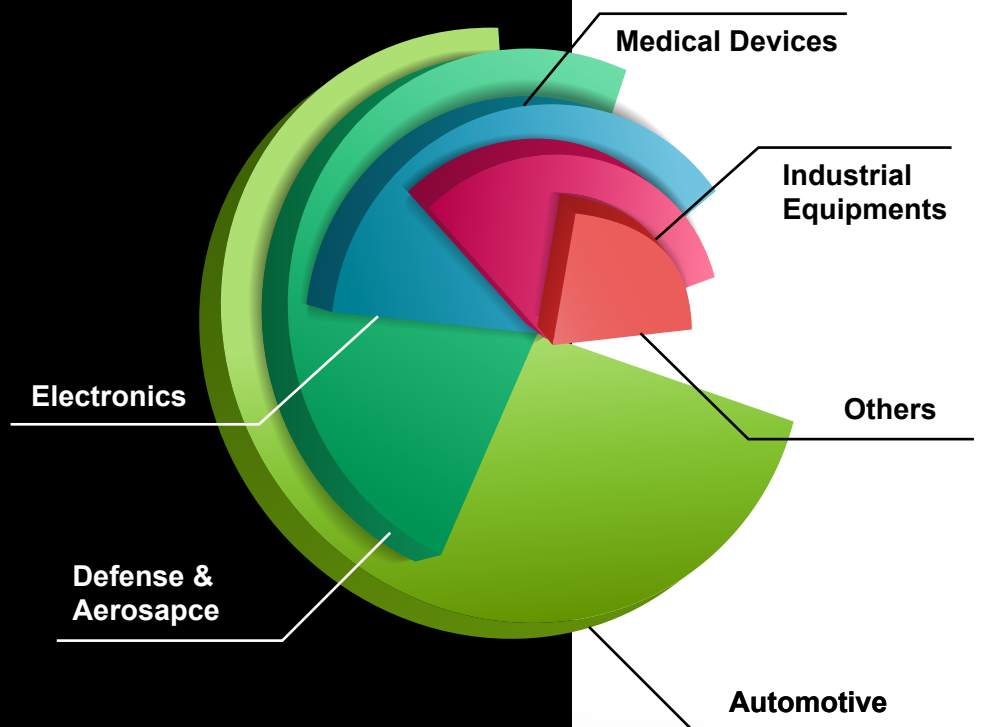


Simulation Software Market

Simulation Software - Growth rate by desiynMarket

In 2022, the automotive end-use industry held the largest market share at 27.06%

- 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, reduces time-to-market, and improving product quality.

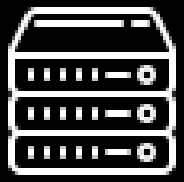
Growing Demand from Automotive and Aerospace Industries: Major contributors to the growth of the CAE simulation market. The need for lightweight materials, fuel efficiency, and safety regulations drive the adoption of CAE simulation tools.

04

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

03

COMPONENT WISE BREAKDOWN OF SIMULATION MARKET



Based on software types, the industry is segmented into Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD), multibody dynamics, and optimization & and simulation. In 2022, the FEA segment accounted for a market share of more than 51% 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 on 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 the application of external forces. Inverse dynamics involves the analysis of forces to move the system in a specific way.

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Market Overview :
Quantum Computing

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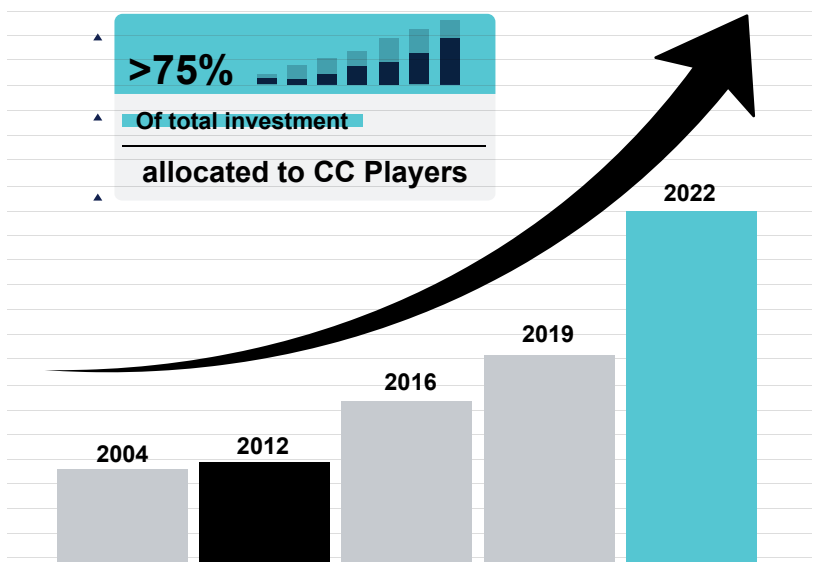
Investments in Quantum Technology reached their highest annual level in 2022 for early stage startups.

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

Annual Raised Start-Up Investment



2022 : $ 2.35 Billion

2021 : $ 2.23 Billion

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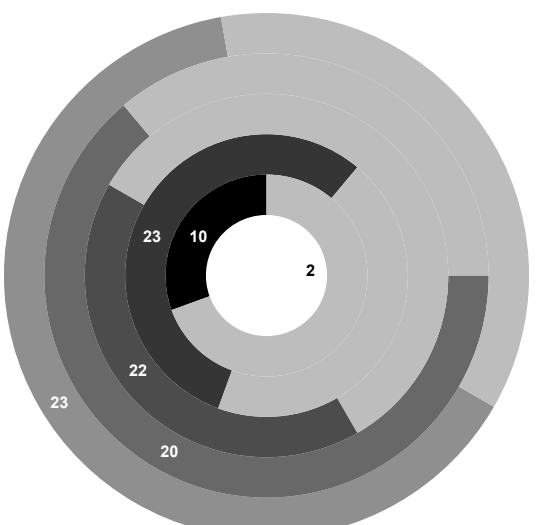
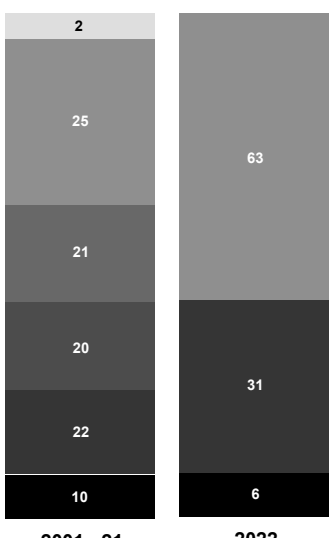
Split of venture capital investments, by deal type,
2001-22, % of total investment value

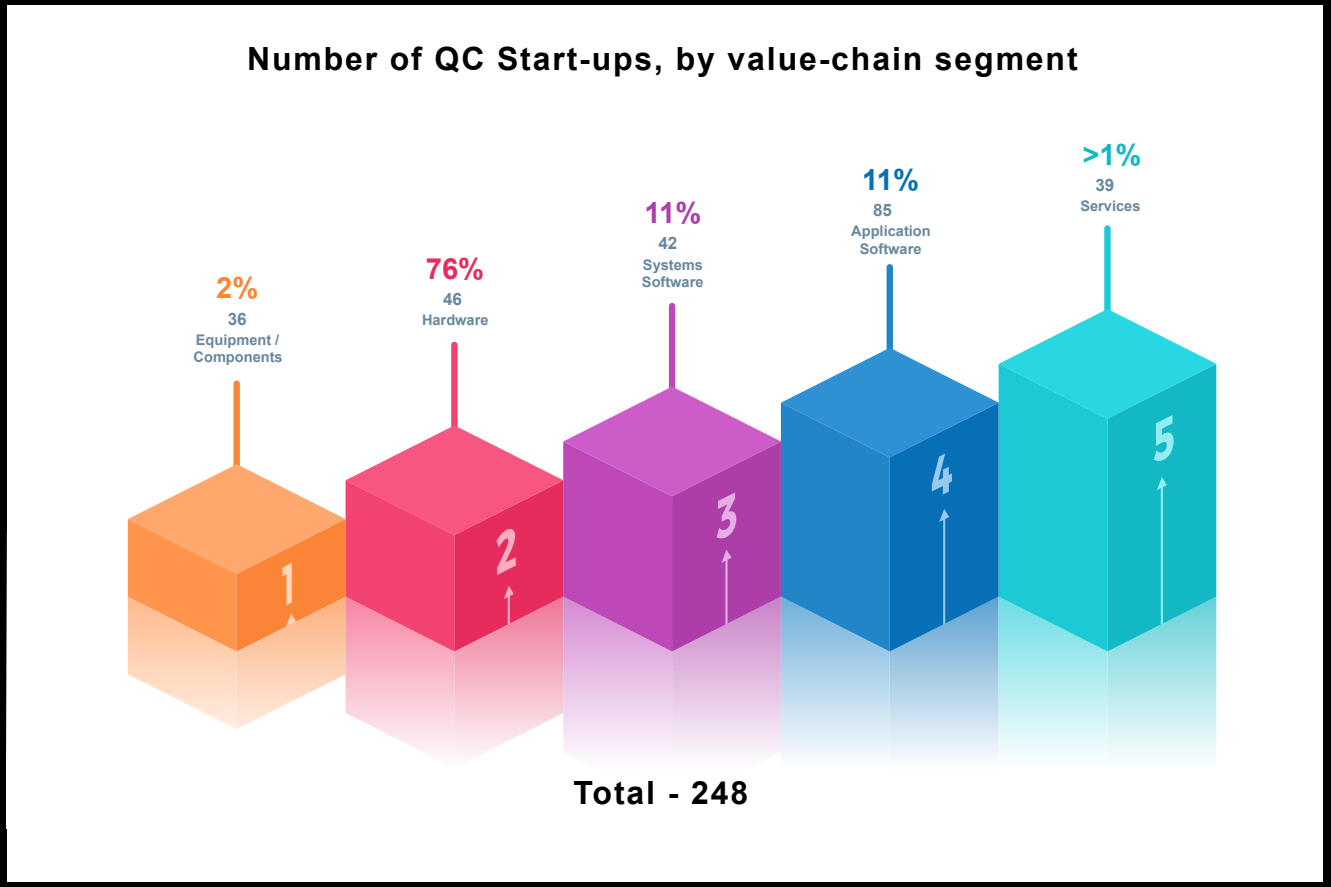


Split of investments, by deal type,
2001-21 vs 2022, % of total investment value

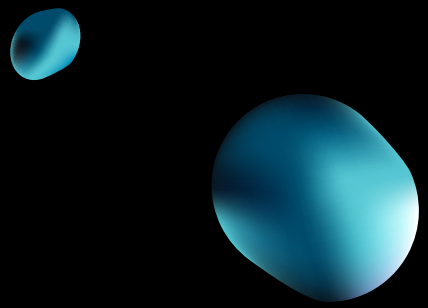


Most investment went to early-stage start-ups in 2022

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 (eg, electronics), scattered across a range of technologies. Product maturity varies per component, yet nearly all components still require customization by quantum players.

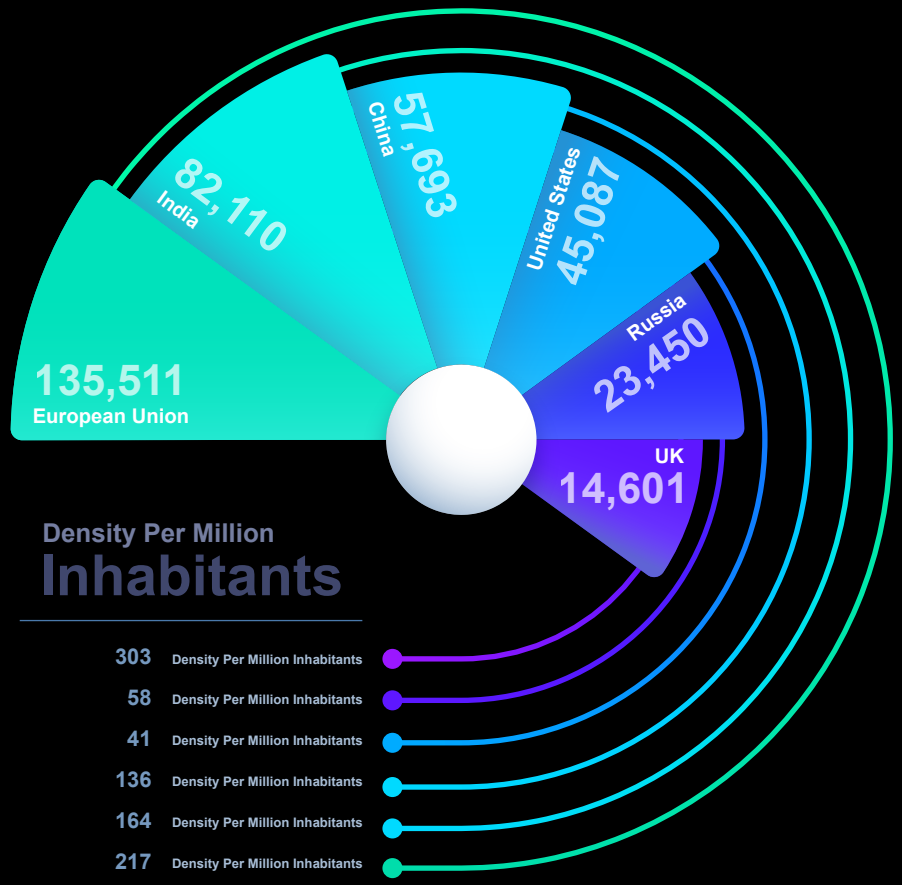


The estimated value at stake for QC in the four industries most likely to see impact first has now reached nearly $1.3 trillion. These industries include Global Energy & materials, Life sciences, Advanced Industries, Automotive and Finance.

Economic Value + Incremental ++ Significant +++ Disruptive

Industry	Key Segment For QC	2025 - 30	2030 - 35
Global Energy and Materials	Oil and Gas	+	++
	Sustainable Energy	+	+++
	Chemicals	++	+++
Life Sciences	Pharmaceuticals	++	+++
Advanced Industries	Automotive	++	++
	Aerospace and Defense	+	++
	Advanced Electronics	+	++
Finance	Semiconductors	+	++
	Financial Services	++	+++
Telecom, Media, and Technology	Telecom	+	++
	Media	+	+
Travel, Transport, and Logistics	Logistics	+	++

The European Union has the highest number and concentration of Quantum Technology Talent.



Absolute number of graduates in Quantum Technology-relevant fields, 2020.

- While the QT talent gap has narrowed, there is still a shortage; upskilling graduates in QT-relevant jobs can help.
- India has the second highest number of graduates in QT.

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

Crypography 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.

Thank You!

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