Integrated Quantum-Classical Applications with CUDA Quantum

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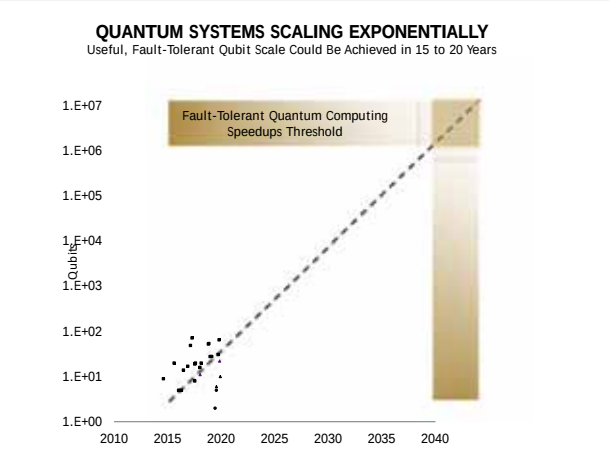
Developer Relations Mgr, Quantum Computing

NVIDIA

Challenges for Useful Quantum Computing



SCALE

100,000+

Total Qubits Required

ALGORITHMS

Unknown

Algorithms for Advantage

FIDELITY

1,000+

Perfect Error Corrected Logical Qubits Required

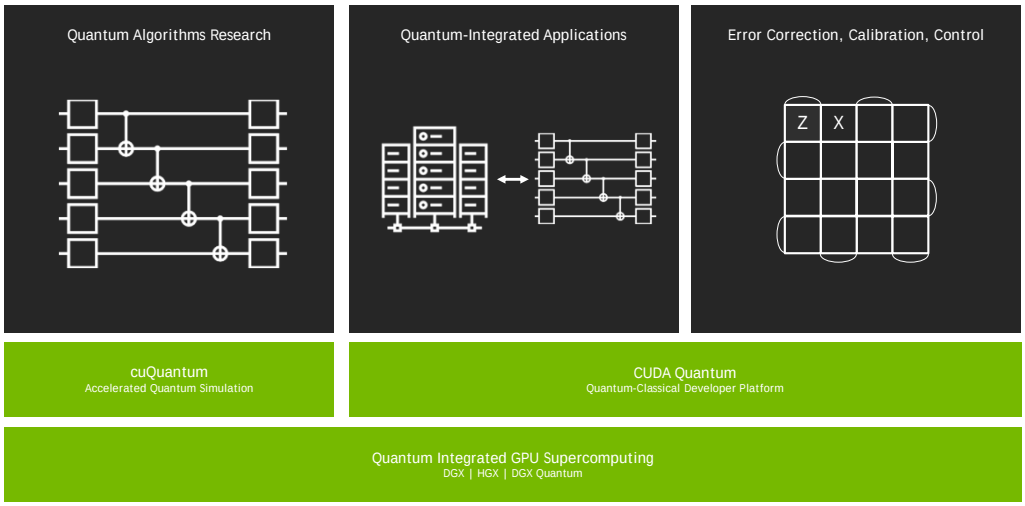
INTEGRATION

Open

Challenge to integrate Quantum in with Classical Supercomputing

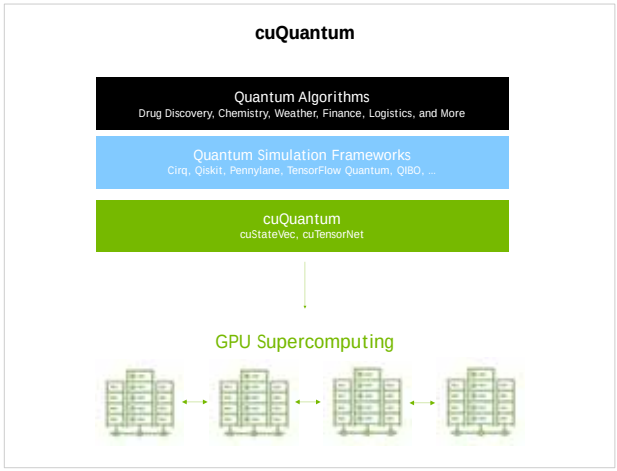
NVIDIA Quantum

Powering Quantum Simulation and Quantum-Integrated Accelerated Computing



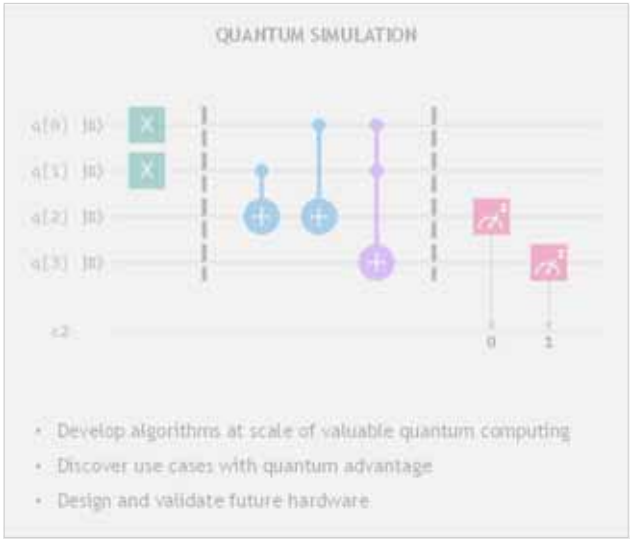
cuQuantum

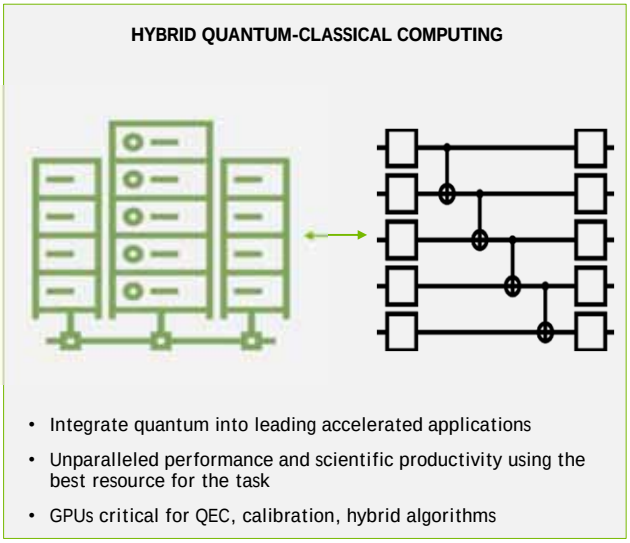
Research the Quantum Computer of Tomorrow on the most Powerful Computer Today



GPU Supercomputing and Quantum

Researching the Quantum Computers of Tomorrow with the Supercomputers of Today

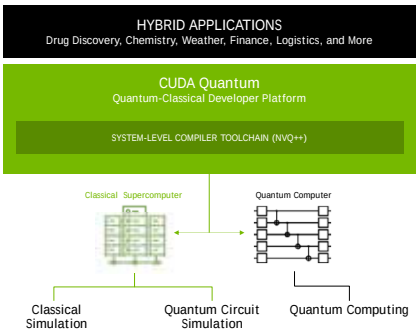




CUDA Quantum: Now Available on GitHub and NGC

A Platform For Quantum-Classical Computing

CUDA QUANTUM PLATFORM



CUDA QUANTUM FEATURES

Supports any kind of QPU, emulated or physical

Compiler for hybrid systems

Open and interoperable with today's applications

Single source C++ and Python programming model

github.com/nvidia/cuda-quantum | https://catalog.ngc.nvidia.com/orgs/nvidia/containers/cuda-quantum

CUDA Quantum: Now Available on GitHub and NGC

Adopted by Community's Leaders to Enable Quantum-Accelerated Applications

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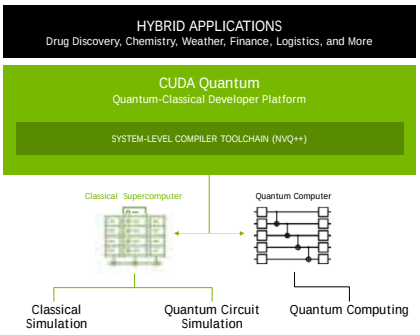

CUDA QUANTUM PARTNERS

ANYON, atom computing, IONQ, IQM, OQC, PASQAL, QUANTUM BRILLIANCE, QUANTINUUM, QuEra Computing Inc., rigetti, XANADU, agnostiq, CLASSIQ, Microsoft, QCWARE, QM ware, ZAPATA

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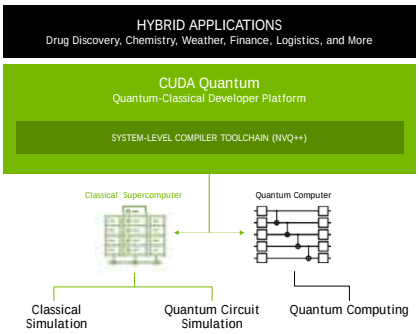
CUDA Quantum: Now Available on GitHub and NGC

Natively Hybrid And Interoperable With GPU Supercomputing

CUDA QUANTUM PLATFORM



Interoperable with GPU Supercomputing

```
auto cnts = cudaq::sample(q, …);
```

Standard Parallelism

```
std::sort(std::execution::par, …);
```

CUDA

```
kernel<<<…>>>(…);
cudaDeviceSynchronize();
```

OpenMP

```
#pragma omp target teams loop
for (…) …
```

OpenACC

```
#pragma acc parallel loop
for (…) …
```

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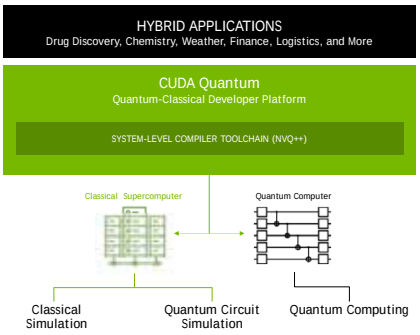

Interoperable with GPU Supercomputing

```
// Compute expectation values with QPU.
cudaq::spin_op h = ...;
std::vector<double> sig_exps;
for (auto& pauli_op : generate_pauli_permutations(h.n_qubits()))
  sig_exps.push_back(cudaq::observe(qite, pauli_op, ...));


...
// Compute LU Factorization of S_mat on the GPU.
auto dim = std::pow(2, h.n_qubits());
cusolverDnXgetrf(handle, params, dim, dim, CUDA_C_64F, S_mat,
                 lda, NULL, CUDA_C_64F,
buffer_on_device,
                 bytes_on_device, buffer_on_host,
                 bytes_on_host, info);
```

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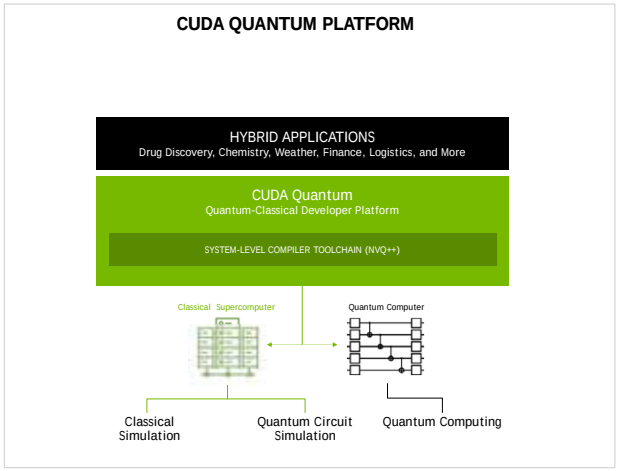
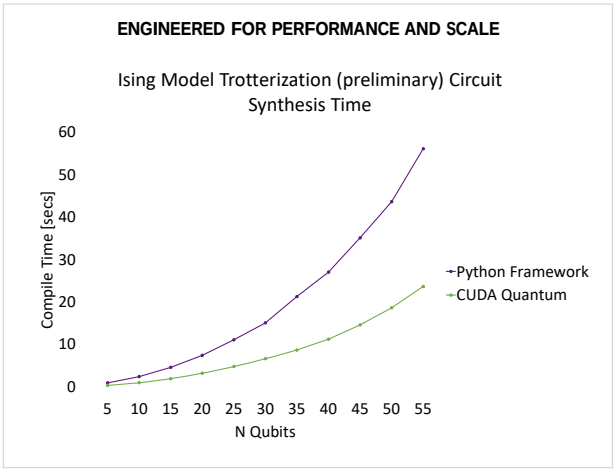
Delivering Unmatched Performance, Scalability, And Usability





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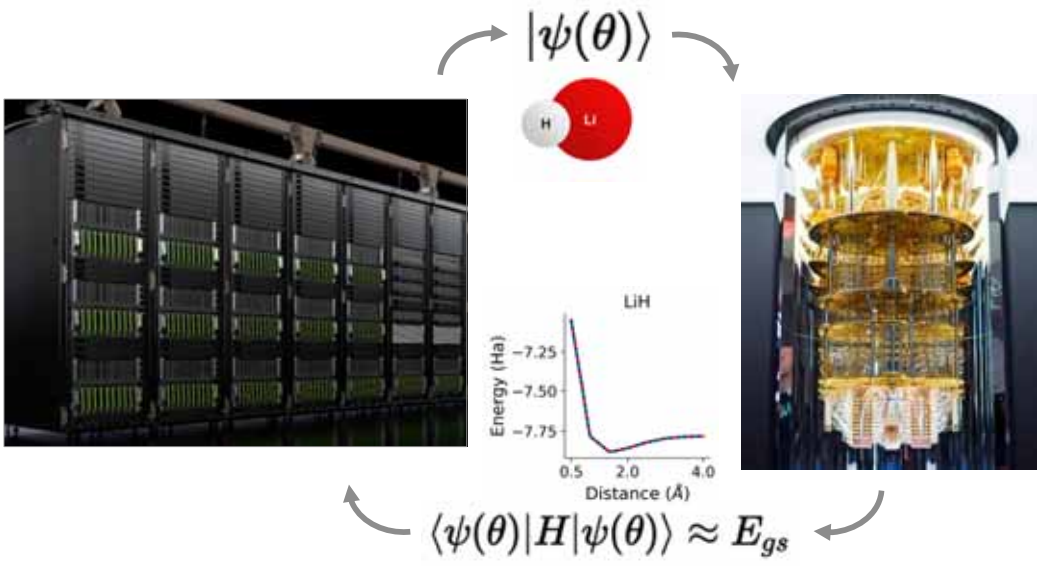
VQE: NVQ++/cuStateVec on A100 GPU vs Leading Pythonic Framework and Simulator with Thrust on A100 GPU

Variational quantum eigensolver (VQE)



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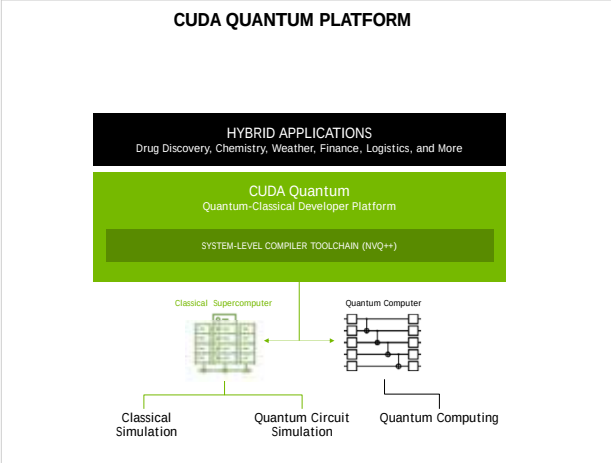

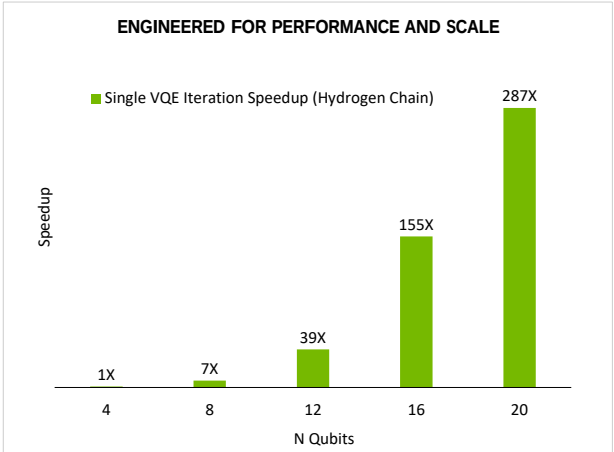

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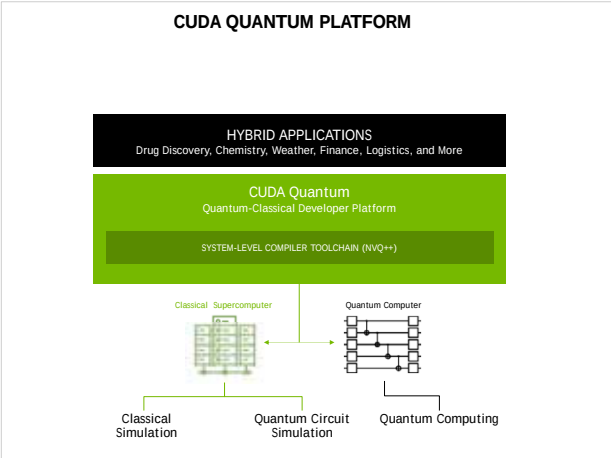
Natively Hybrid And Interoperable With GPU Supercomputing



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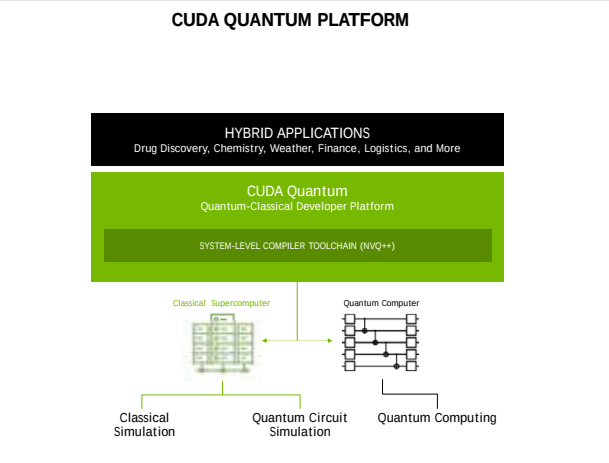
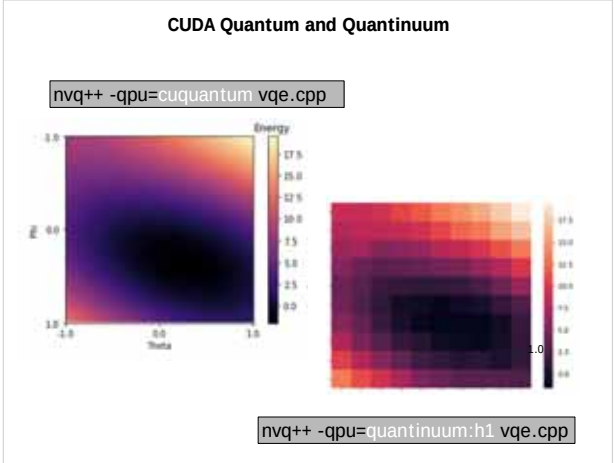
CUDA Quantum: Now Available on GitHub and NGC

Seamlessly Target any Quantum Resource





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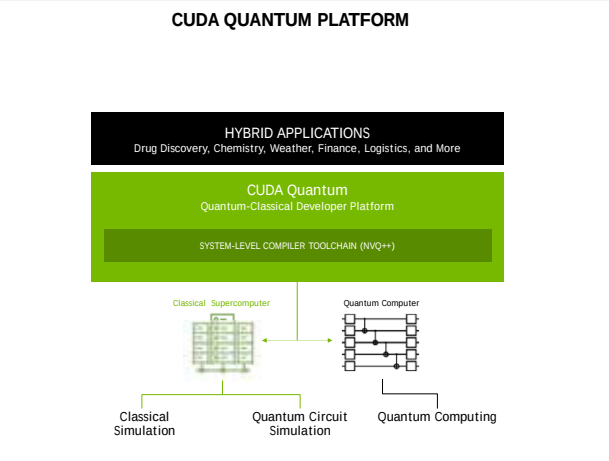

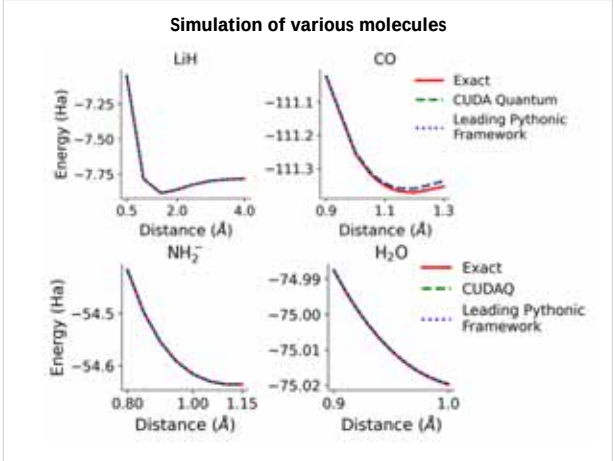

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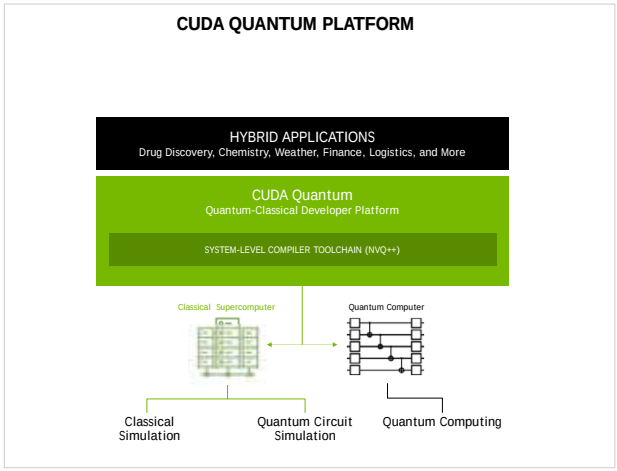

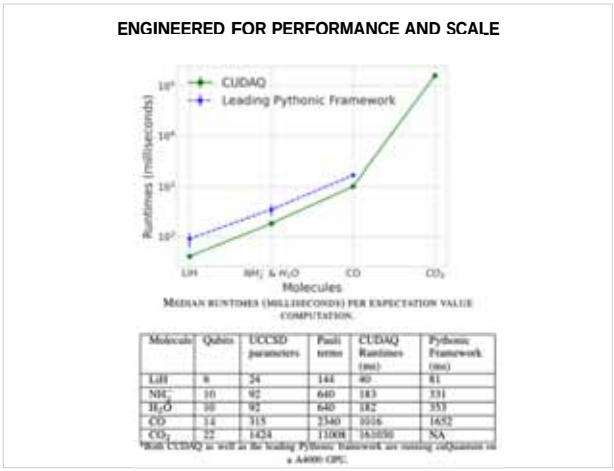

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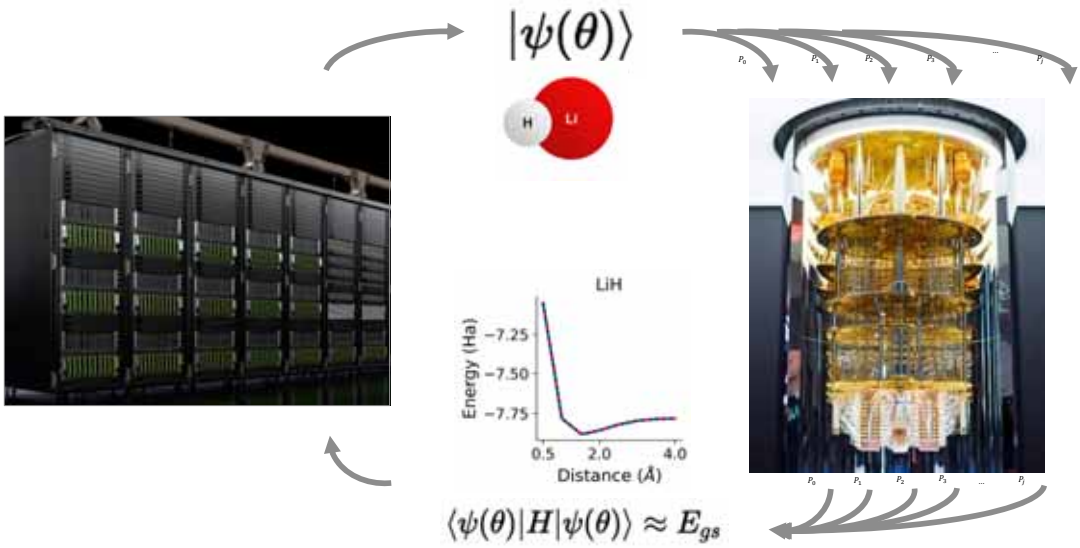
Novel Configurations with CUDA Quantum



j=11,008 for CO2

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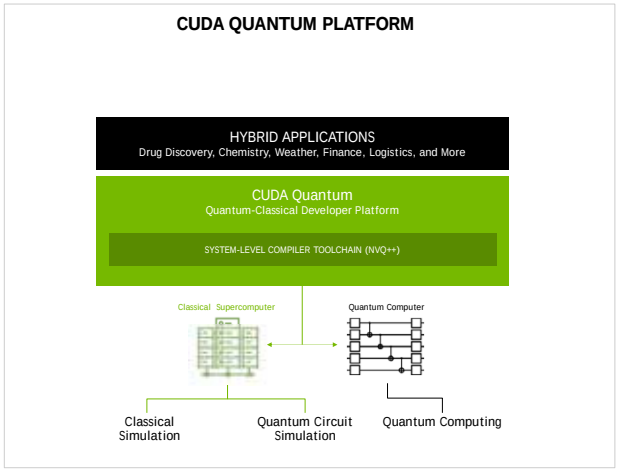

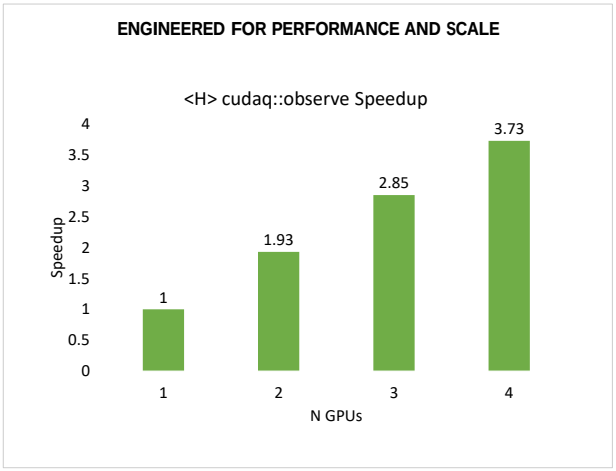

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GPU Supercomputing and Quantum

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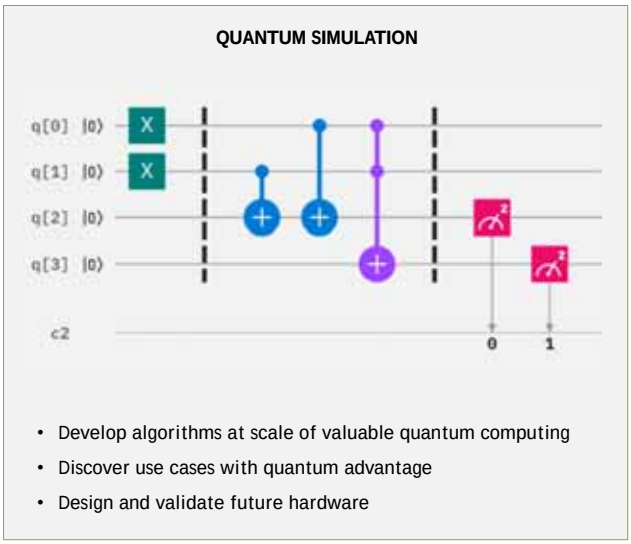
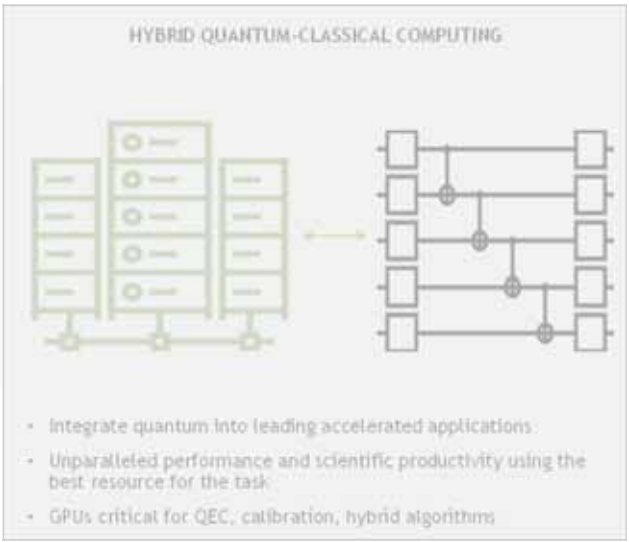


- Develop algorithms at scale of valuable quantum computing
- Discover use cases with quantum advantage
- Design and validate future hardware



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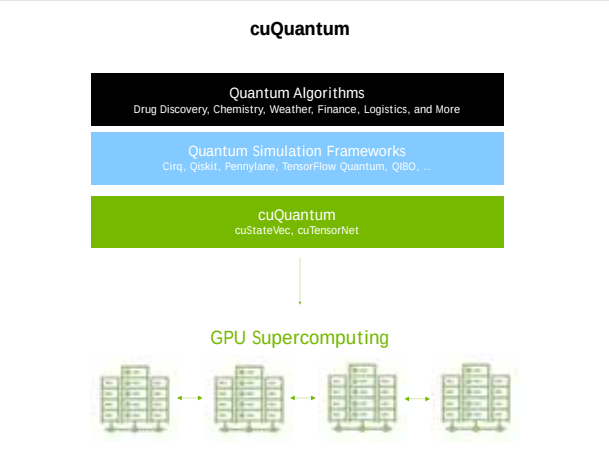

SDK for GPU Accelerated Quantum Simulation

Simulate Ideal or Noisy Qubits with State Vector or Tensor Network methods

Supports GPU Supercomputing with Multi-Node Multi-GPU Circuit Simulation

Integrated into all leading frameworks

Optimized frameworks in cuQuantum Appliance: catalog.ngc.nvidia.com/orgs/nvidia/containers/cuquantum-appliance

- **Now available as VMI on all major Clouds**

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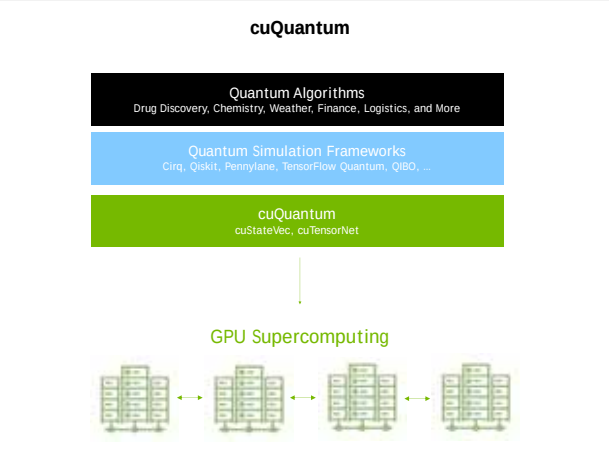

cuQuantum Accelerated Frameworks

aws, bluegat, BlueQubit, Cirq, CLASSIQ, Orquestra, PENNYLANE, qBraid, QIBO, Qiskit, TensorFlow Quantum, Torch Quantum, XACC

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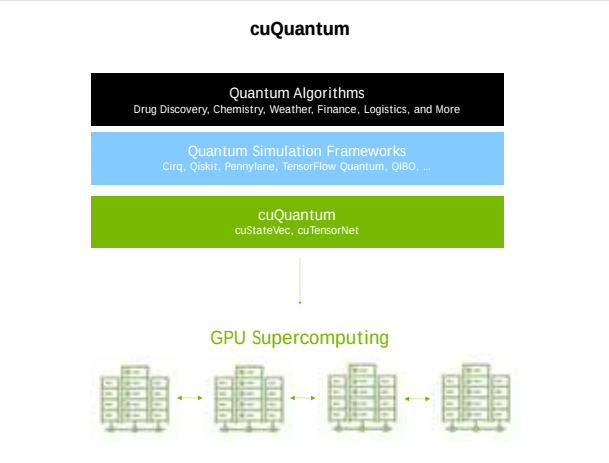

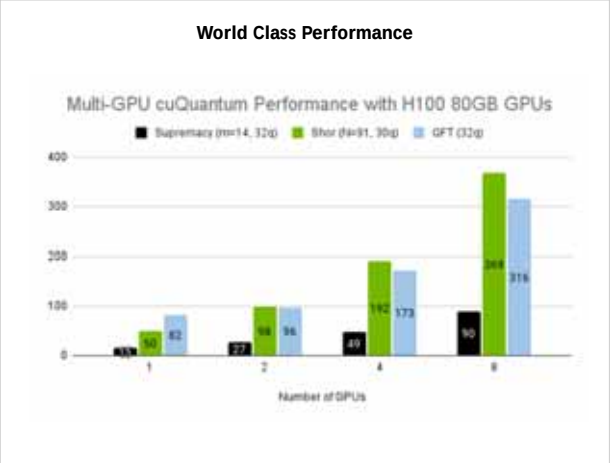

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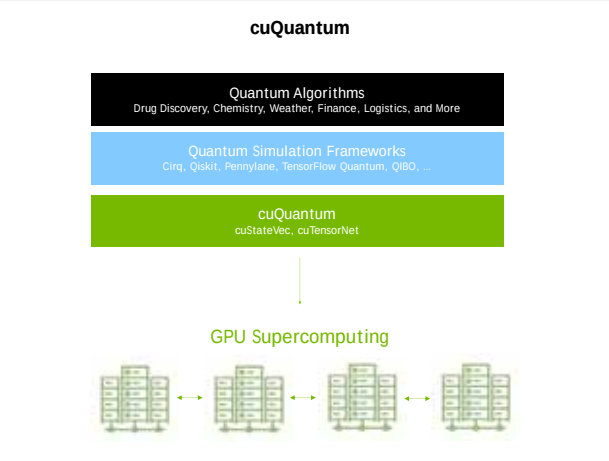

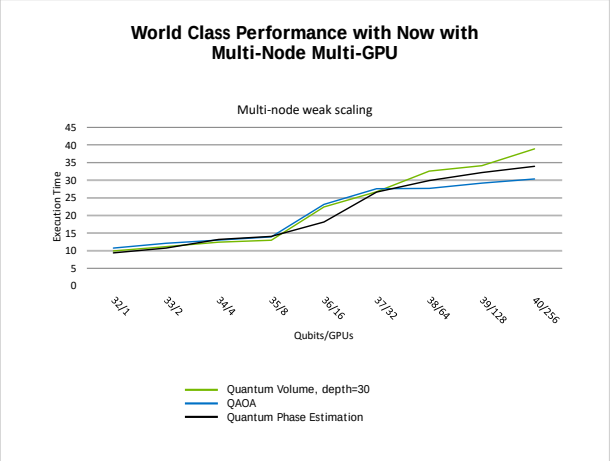

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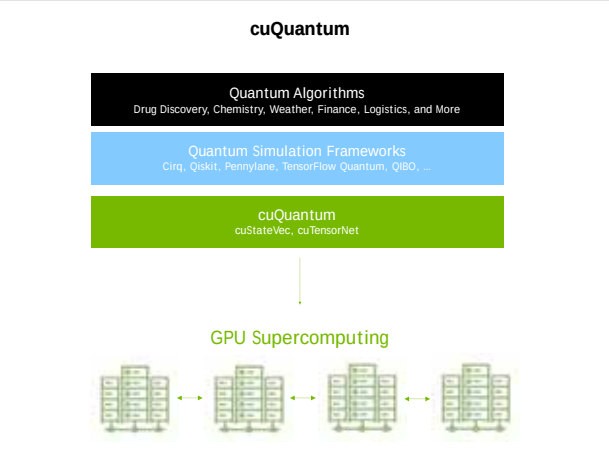

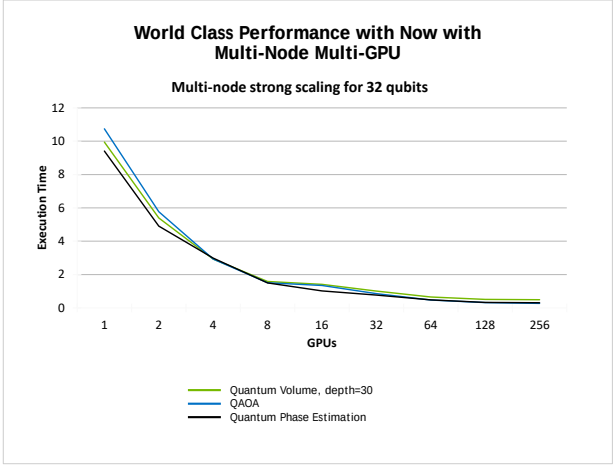

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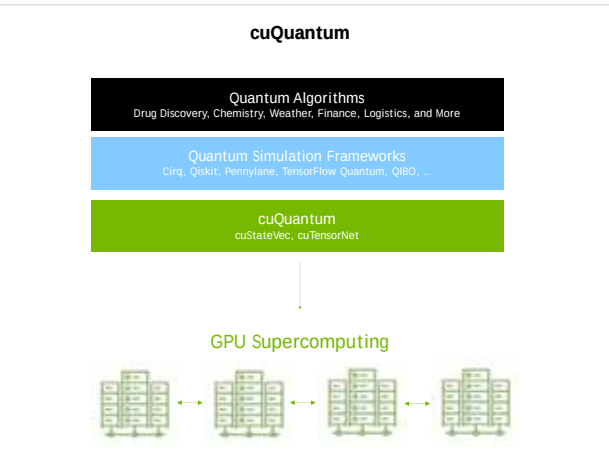

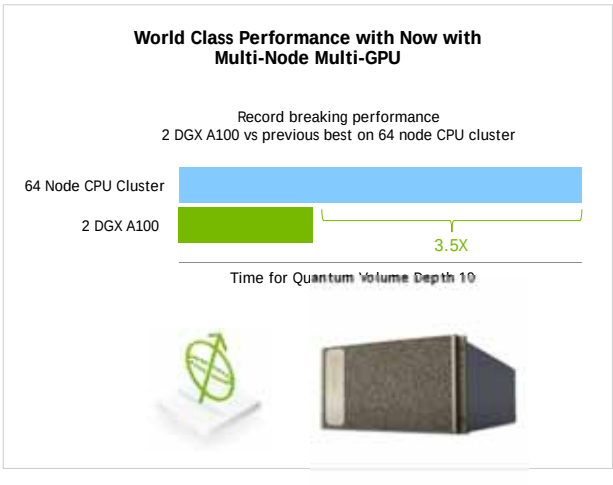

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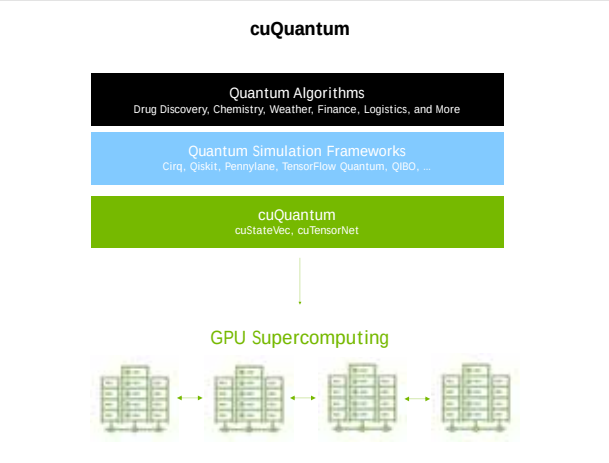

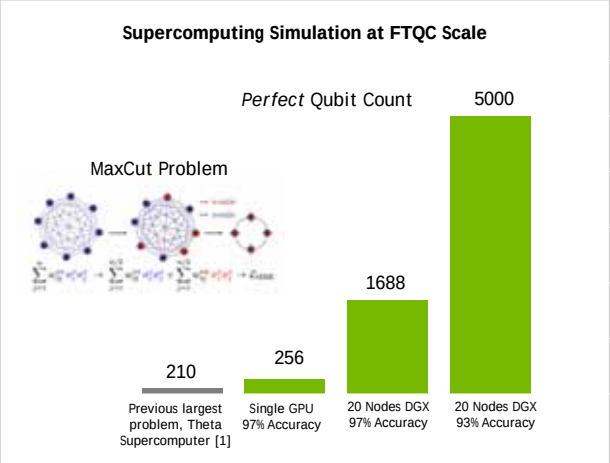

[1] Danylo Lykov et al, Tensor Network Quantum Simulator With Step-Dependent Parallelization, 2020 https://arxiv.org/pdf/2012.02430.pdf

NVIDIA Quantum

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