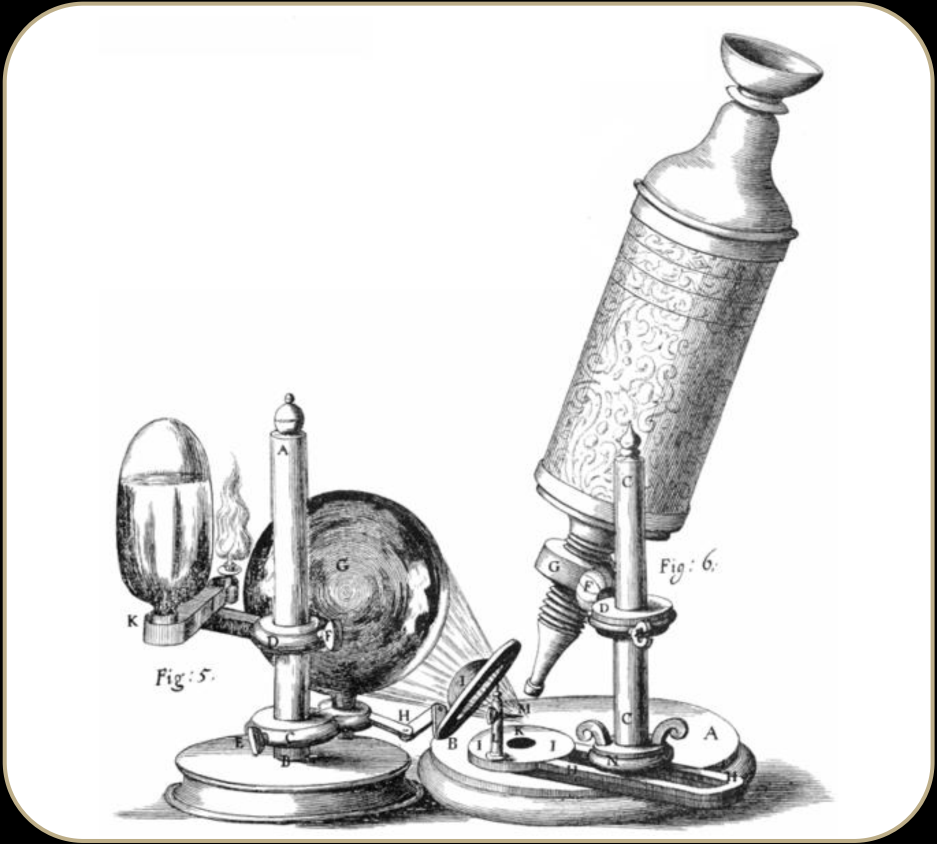
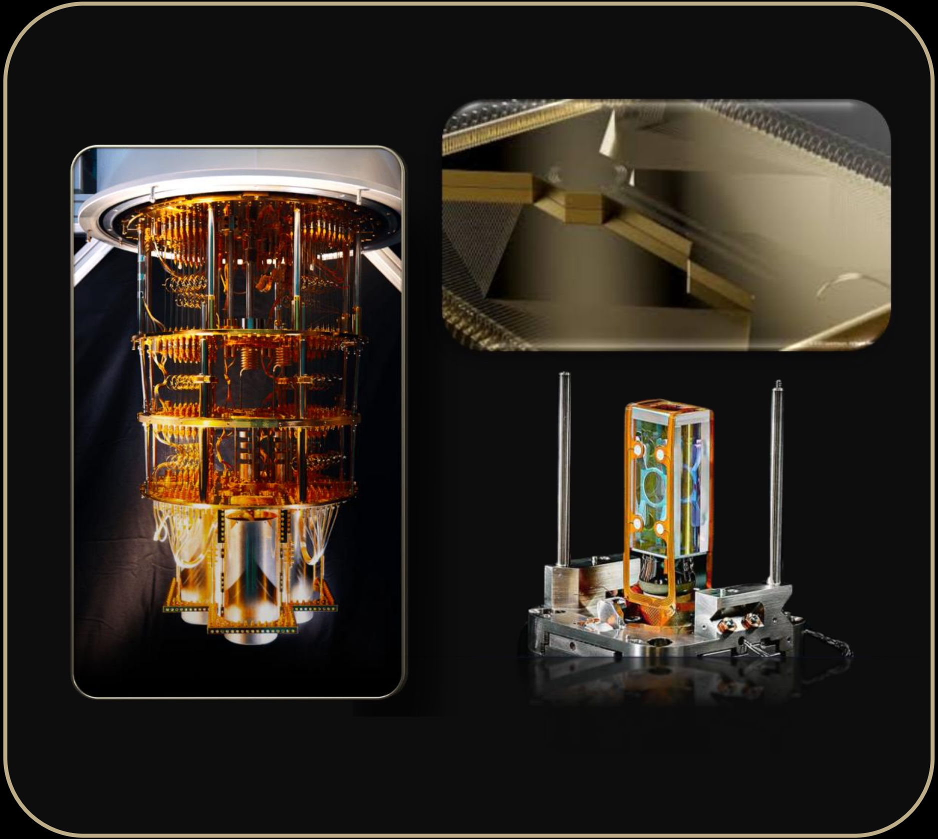
# Accelerated Quantum Supercomputing

Esperanza Cuenca-Gomez, Developer Relations Manager, Quantum Computing

# The Next Great Instrument for Scientific Discovery




Robert Hooke's Microscope, 1664

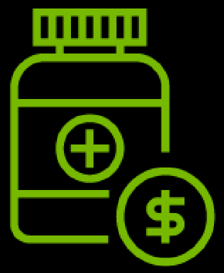


Quantum Processors, today

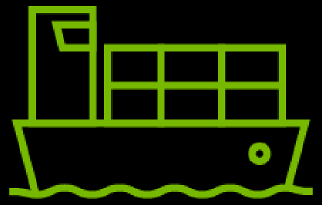
# Quantum Computing’s Broad Impact

Development occurring faster than expected

EV chemistry

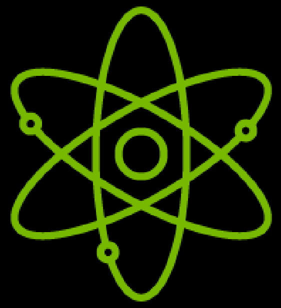


Drug discovery

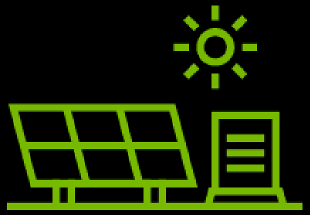


Logistics

Finance

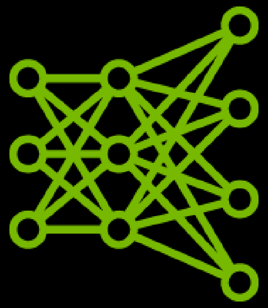


Physics modelling



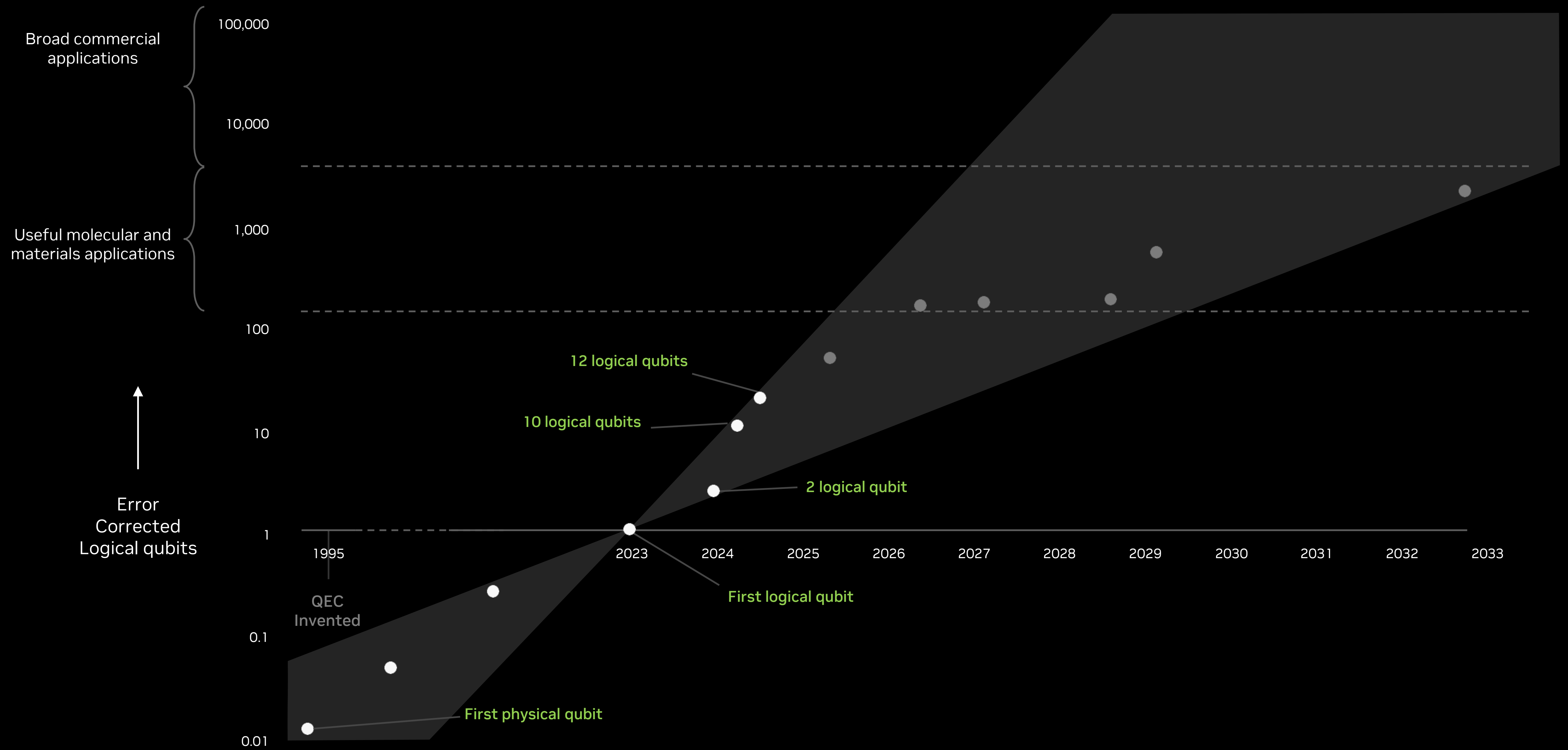
Materials

Nitrogen fixation



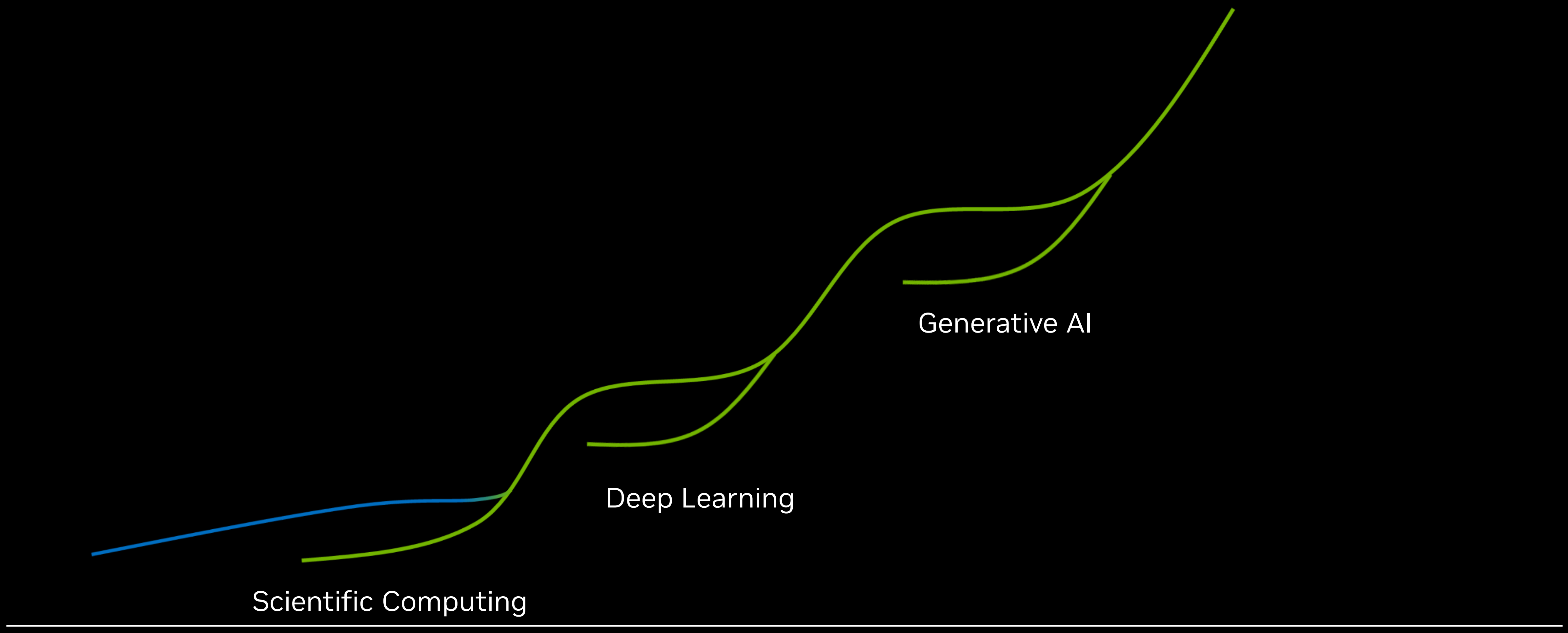
AI and ML

# Quantum Computing is at an Inflection Point

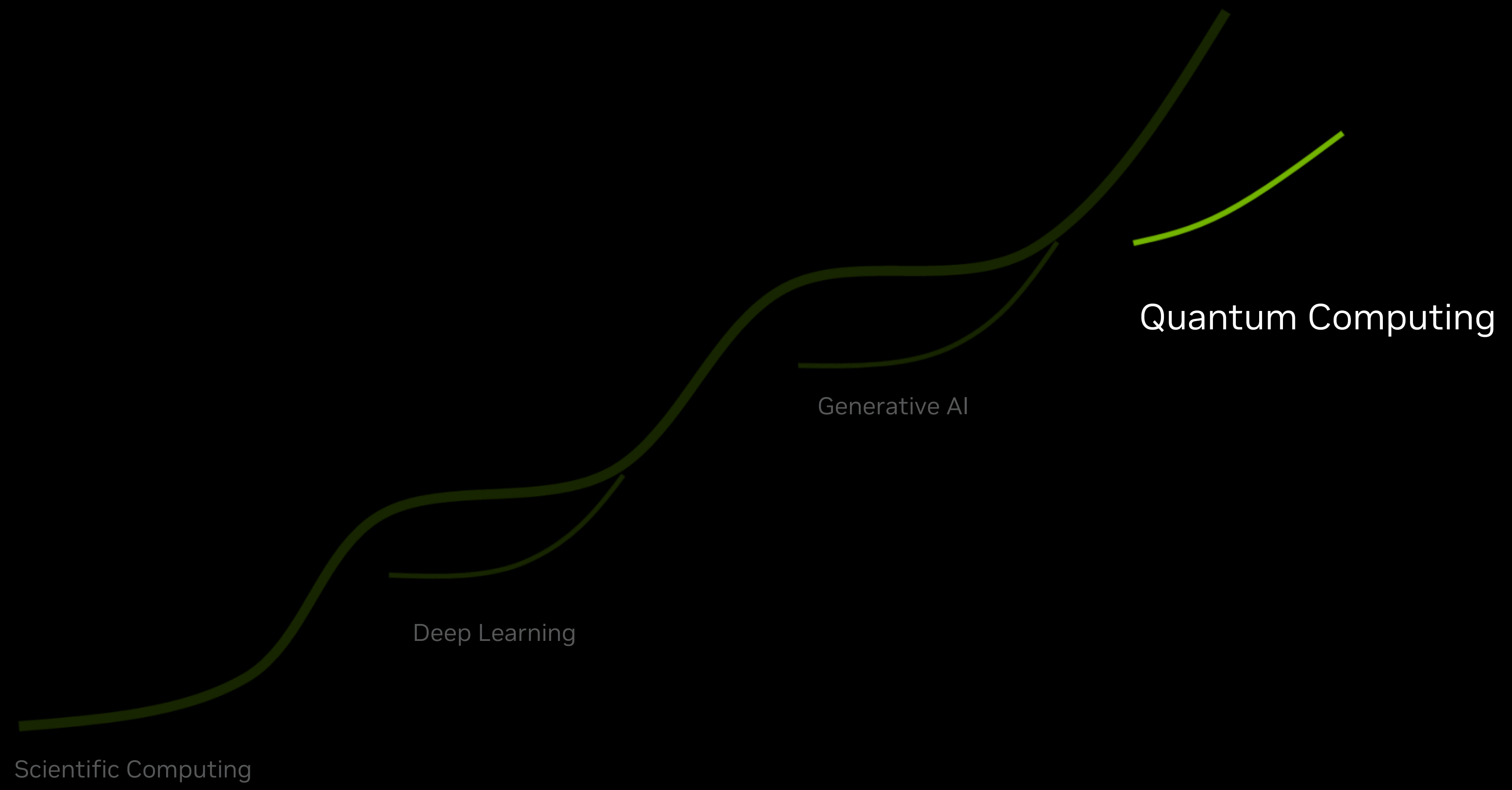



NVIDIA

# NVIDIA's History of Enabling Computing Revolutions



# NVIDIA's History of Enabling Computing Revolutions



NVIDIA is not building
Qubits

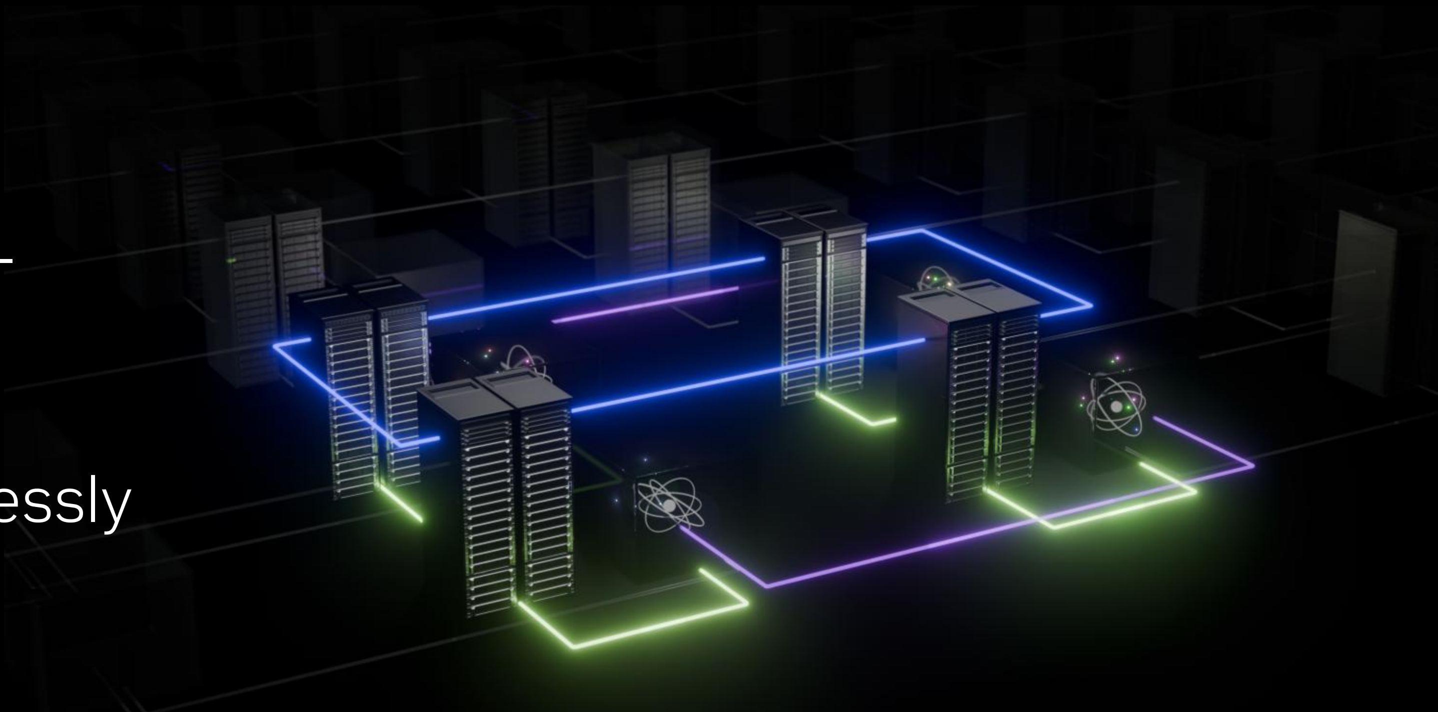
NVIDIA is building all

Accelerated Quantum

Supercomputers

# The Accelerated Quantum Supercomputer

- Supercomputing architecture **connecting quantum hardware**
- Ability to run **hybrid algorithms** - using GPUs and QPUs
- A **software platform** that seamlessly connects hybrid applications
- The ability to perform **qubit-agnostic** development of control and error correction



# Powering the Quantum Ecosystem

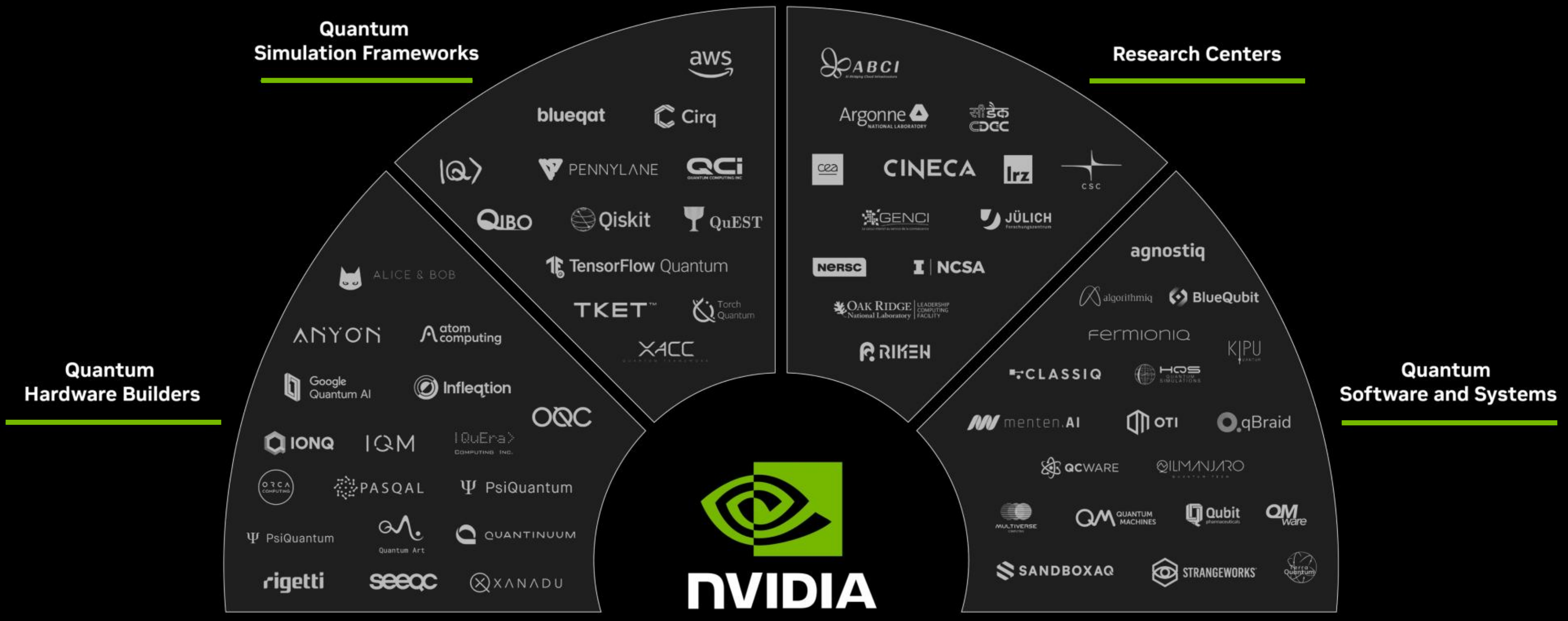
The only quantum company that works with every other quantum company

**200+**
NVIDIA Quantum Partners

**>90%**
Largest Startups Working with NVIDIA

**>80%**
QPUs Integrating NVIDIA Software

**100%**
Leading Quantum Development Frameworks Accelerated



# The NVIDIA Quantum Ecosystem

## Accelerating the Quantum World

agnostiq | algorithmiq | ALICE & BOB | Amazon Braket | ANYON | Anyon Technologies | ATLANTIC QUANTUM

atom computing | blueqat | BlueQubit | CLASSIQ | diraq | D:WAVE

Entropica Labs | equal1 | fermioniq | Google Quantum AI | HQS QUANTUM SIMULATIONS | horizon quantum | Infleqtion

|Q> | IQM | IONQ | Kipu | menten.AI | Microsoft | Nord Quantique | ORCA COMPUTING | OQC

OTI | Pasqal | PENNYLANE | .PLANQ | PsiQuantum | qBraid | QCDESIGN

QCi QUANTUM COMPUTING INC. | QCWARE | QIBO | QILIMANJARO | Qiskit | QM QUANTUM MACHINES | QMware | QUANDELA

QUANTINUUM | Quantum Art | QUANTUM BRILLIANCE | QUANTUM ELEMENTS | Quantum Rings | Qubit PHARMACEUTICALS

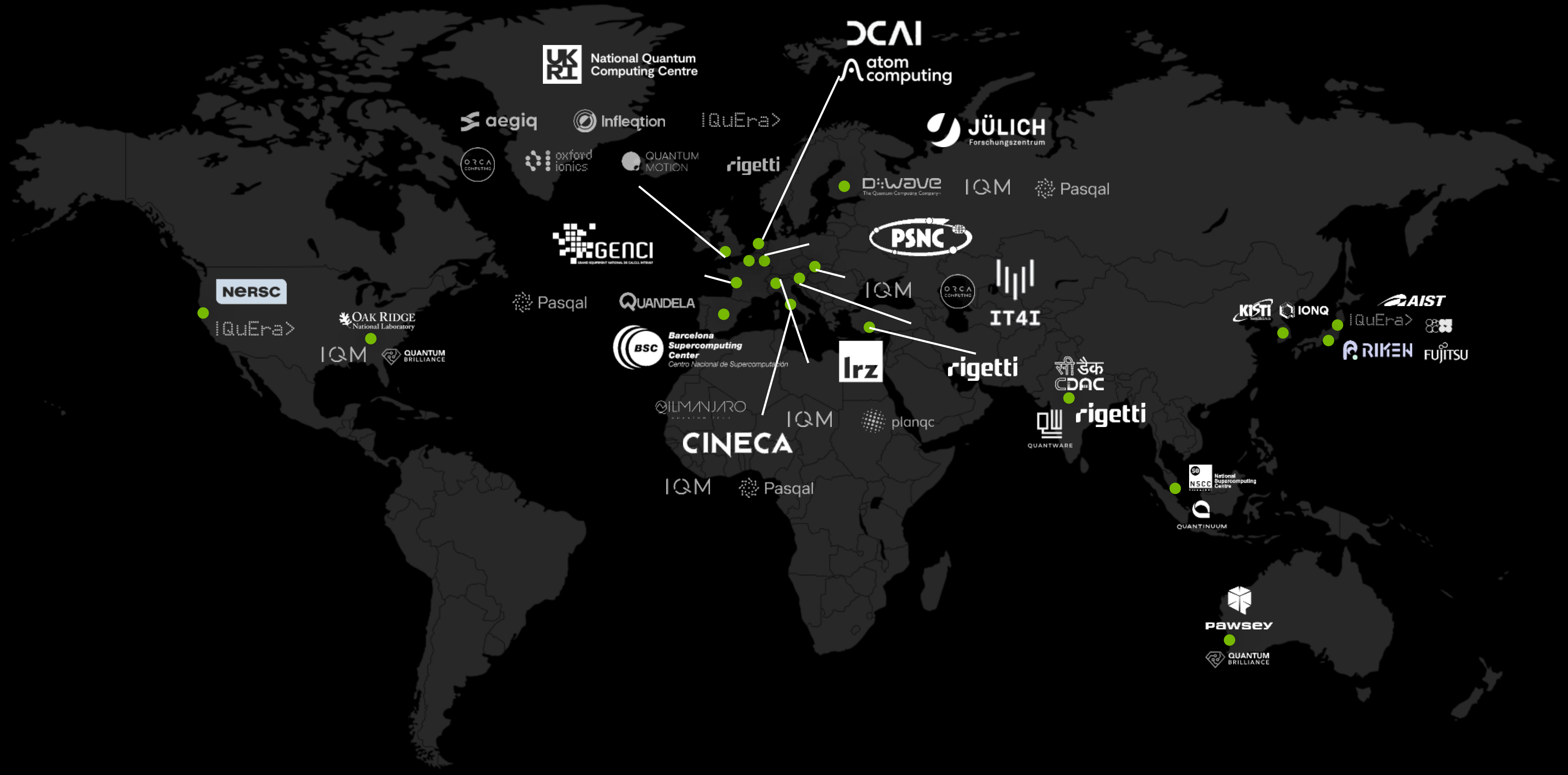
|QuEra> | QUDORA TECHNOLOGIES | QuEST | quobly | rigetti | seeqc | STRANGEWORKS

SANDBOXAQ | Terra Quantum | TKET | Torch Quantum | XACC | XANADU

# NVIDIA and Europe Building Quantum-GPU Computing

**cuQuantum**
**CUDA-Q**
Quantum
Computing

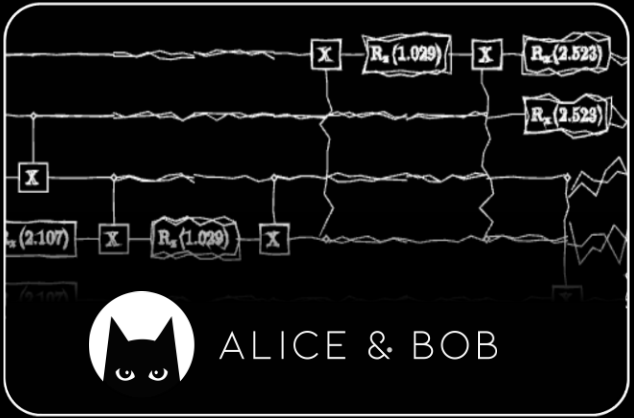
# Supercomputing Centers are the Home of Quantum Breakthroughs



# Accelerating Quantum Workloads Across Europe

Quantum Algorithm Development

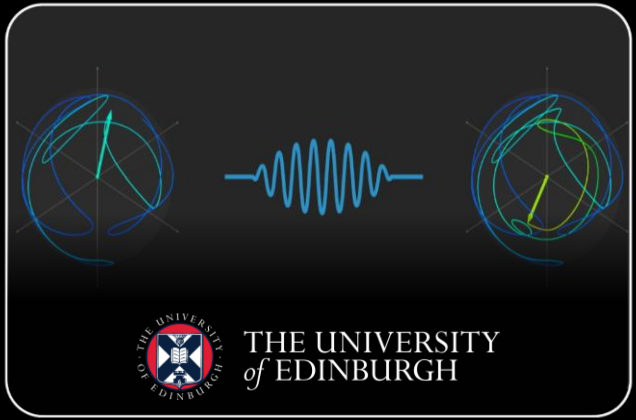

Quantum EDA




Quantum Data Generation


Hybrid Applications


Quantum Error Correction



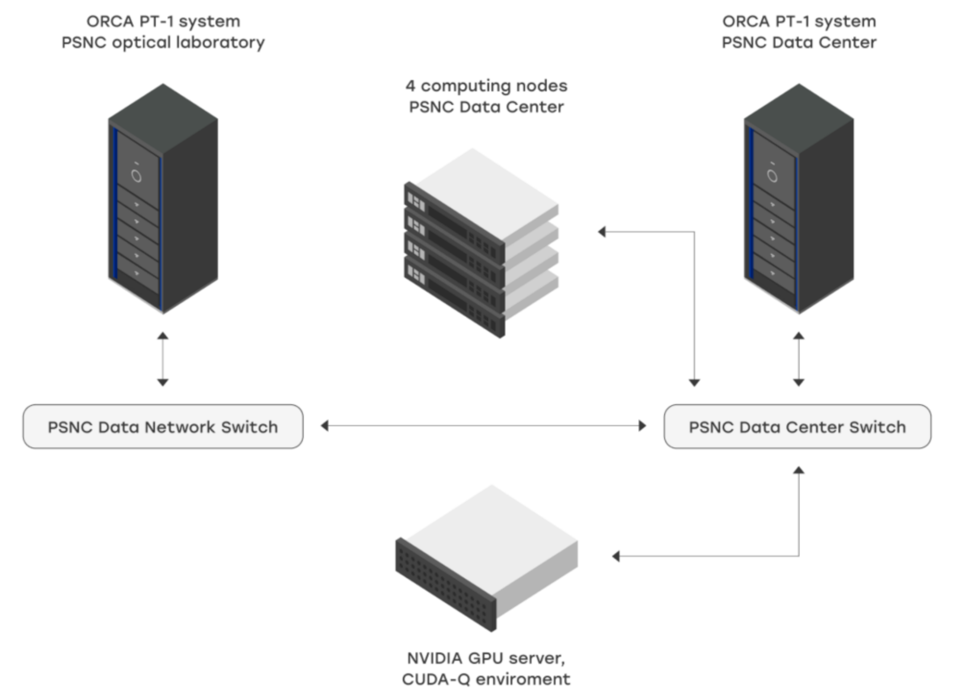
# The Accelerated Quantum Supercomputer

## The ORCA Computing and PCSS collaboration with NVIDIA

PSNC ORCA COMPUTING NVIDIA

Blog | November 18, 2024

## World's First Multi-QPU, Multi-GPU, Multi-CPU Quantum Use Case Demonstration




PSNC ORCA COMPUTING IMPERIAL NVIDIA

## ORCA Computing, PCSS and Imperial College collaborate with NVIDIA to demonstrate a distributed quantum neural network in a hybrid HPC environment

SEP 16 2025

Quantum computing is rapidly evolving from theory to practice, and a key step on that journey is the integration of quantum processors with the high-performance computing (HPC) systems that already underpin today's AI and scientific workloads. Researchers from ORCA Computing, the Poznan Supercomputing Networking Center (PCSS) and Imperial College London, in collaboration with NVIDIA, are working to achieve this integration and develop algorithms that can leverage it.

Here, we announce a first demonstration of a distributed photonic quantum neural network on a hybrid HPC environment. This work highlights the potential of quantum photonic processors as building blocks in distributed machine learning architectures. By coupling quantum devices to GPU nodes, we can expand the capabilities of classical neural networks with new quantum methods and optimization pathways.

This work leverages the world's first HPC environment allowing multiple users to access a multi-QPU and multi-GPU environment, which used the CUDA-Q platform to combine ORCA quantum processors and NVIDIA GPUs. We are pleased to announce the release of our first paper describing this environment, which also presents additional applications in machine learning and optimization.

### Hybrid Classical-Quantum Supercomputing: A demonstration of a multi-user, multi-QPU and multi-GPU environment


Mateusz Slysz[1], Piotr Rydlichowski[1], Krzysztof Kurowski[1], Omar Bacarreza[3], Esperanza Cuenca Gomez[2], Zohim Chandani[2], Bettina Heim[2], Pradnya Khalate[2], William R. Clements[3], and James Fletcher[3]*

[1] *Poznanskie Centrum Superkomputerowo-Sieciowe*
[2] *NVIDIA*
[3] *ORCA Computing*



Achieving a practical quantum advantage for near-term applications is widely expected to rely on hybrid classical-quantum algorithms. To deliver this practical advantage to users, high performance computing (HPC) centers need to provide a suitable software and hardware stack that supports algorithms of this type. In this paper, we describe the world's first implementation of a classical-quantum environment in an HPC center that allows multiple users to execute hybrid algorithms on multiple quantum processing units (QPUs) and GPUs. Our setup at the Poznan Supercomputing and Networking Center (PCSS) aligns with current HPC norms: the computing hardware including QPUs is installed in an active data center room with standard facilities; there are no special considerations for networking, power, and cooling; we use Slurm for workload management as well as the NVIDIA CUDA-Q extension API for classical-quantum interactions. We demonstrate applications of this environment for hybrid classical-quantum machine learning and optimisation. The aim of this work is to provide the community with an experimental example for further research and development on how quantum computing can practically enhance and extend HPC capabilities.

# The Generative Quantum Eigensolver

First demonstration of GPT-generated circuits in the literature

## The generative quantum eigensolver (GQE) and its application for ground state search

Kouhei Nakaji[1,2,3], Lasse Bjørn Kristensen[1,4], Jorge A. Campos-Gonzalez-Angulo *[1], Mohammad Ghazi Vakili *[1,4], Haozhe Huang *[4,5], Mohsen Bagherimehrab †[1,4], Christoph Gorgulla †[6,7], FuTe Wong[4,8], Alex McCaskey[9], Jin-Sung Kim[9], Thien Nguyen[9], Pooja Rao[9], and Alan Aspuru-Guzik[1,4,5,10,11,12]

[1] Chemical Physics Theory Group, Department of Chemistry, University of Toronto, Toronto, Ontario, Canada
[2]Research Center for Emerging Computing Technologies, National Institute of Advanced Industrial Science and Technology (AIST), 1-1-1 Umezono, Tsukuba, Ibaraki, Japan
[3]Quantum Computing Center, Keio University, 3-14-1 Hiyoshi, Kohoku-ku, Yokohama, Kanagawa, Japan
[4]Department of Computer Science, University of Toronto, Toronto, Ontario, Canada
[5]Vector Institute for Artificial Intelligence, Toronto, Ontario, Canada
[6]Department of Physics, Faculty of Arts and Sciences, Harvard University, Cambridge, Massachusetts, USA
[7]Department of Structural Biology, St. Jude Children's Research Hospital, Memphis, Tennessee, USA
[8]Institute of Medical Science, University of Toronto, Toronto, Ontario, Canada
[9]NVIDIA, Santa Clara, California, USA
[10]Department of Chemical Engineering & Applied Chemistry, University of Toronto, Toronto, Ontario, Canada
[11]Department of Materials Science & Engineering, University of Toronto, Toronto, Ontario, Canada
[12]Lebovic Fellow, Canadian Institute for Advanced Research, Toronto, Ontario, Canada



We introduce the generative quantum eigensolver (GQE), a novel method for applying classical generative models for quantum simulation. The GQE algorithm optimizes a classical generative model

tably, recent research reports the experimental realization of quantum computing with 48 logical qubits [1], marking the onset of the early fault-tolerant quantum computing regime. However, despite these

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Finding cures. Saving children.

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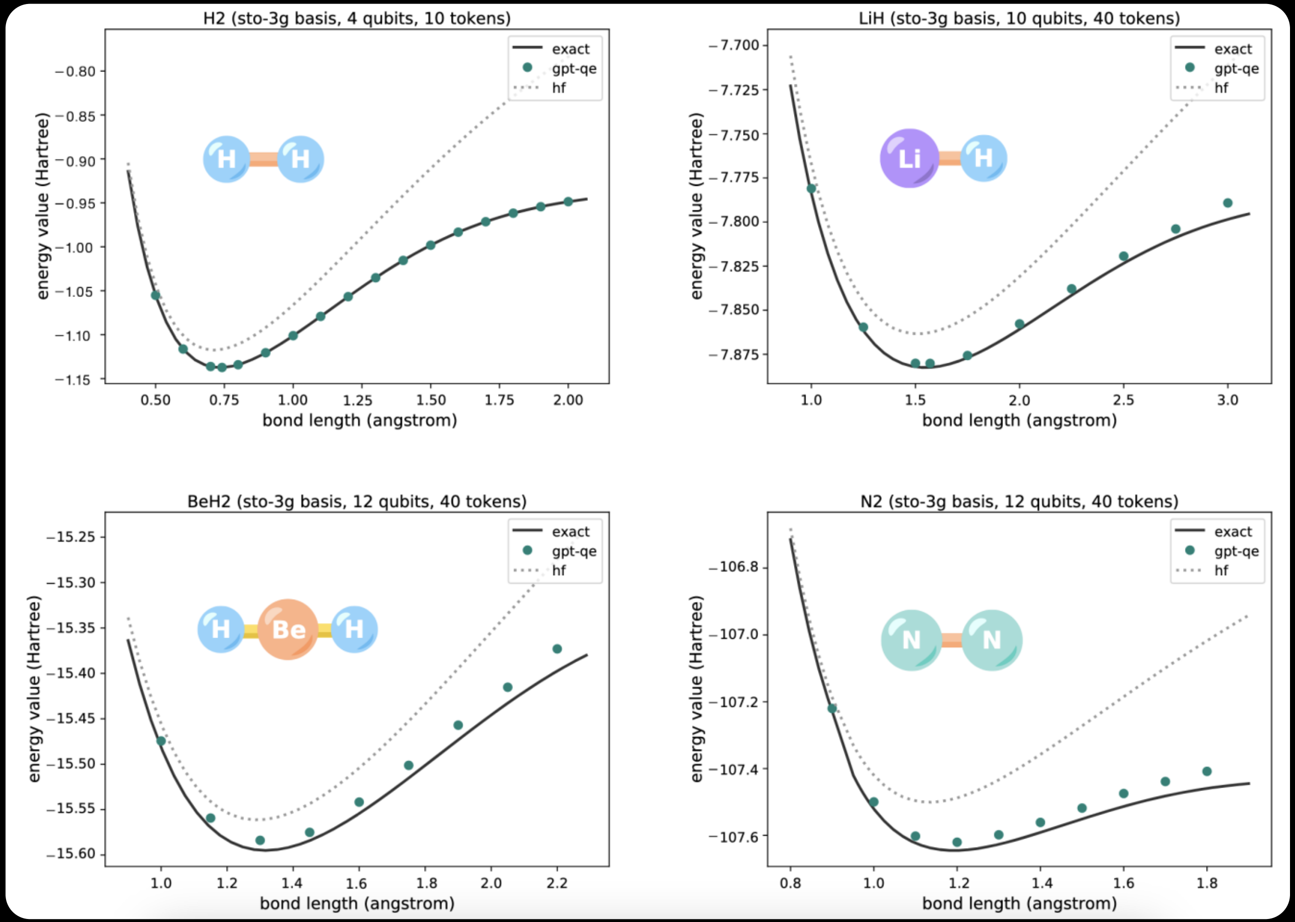
# Application to Ground State Search

GTP-QE used to generate circuits producing a molecular ground state

- **Clear example of leveraging AI for QC**
- **Executed using CUDA-Q on A100 GPUs in Perlmutter supercomputer**
- **Can be extended to variety of novel Generative Quantum Algorithms (GQAs)**
  - Potential extensions in drug discovery, materials science, and environmental applications.

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St. Jude Children's Research Hospital
Finding cures. Saving children.

https://arxiv.org/pdf/2401.09253.pdf

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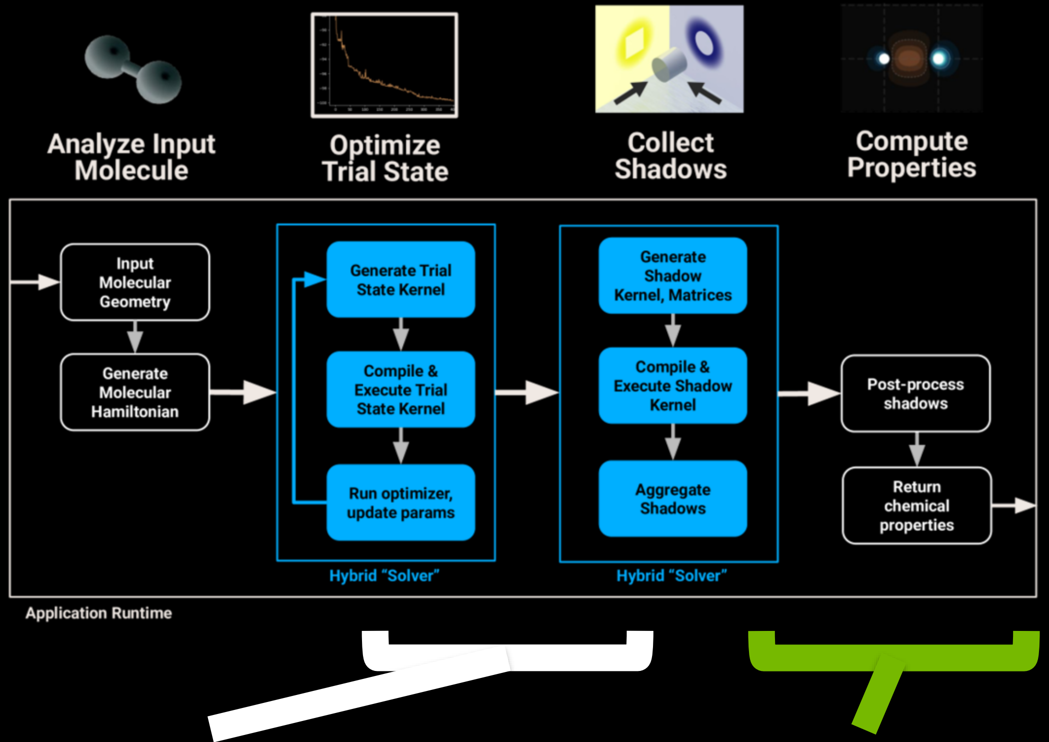
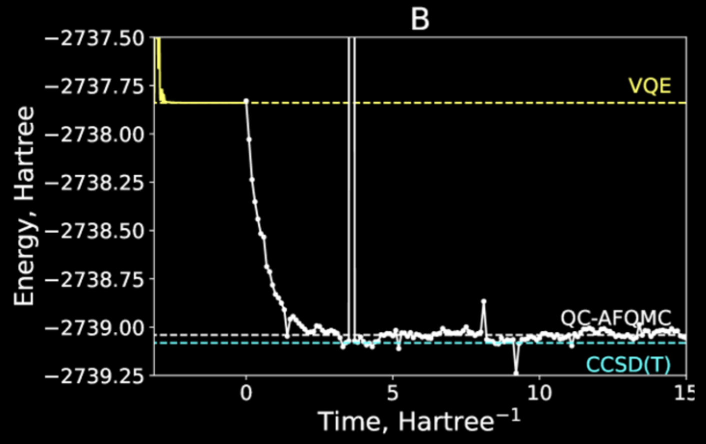
# Quantum-GPU Computing for Medicinal Chemistry

- Hybrid algorithm to model chemical reaction barriers
- 20q trial state prepared on IonQ Forte with CUDA-Q
- 320x H200 GPUs on AWS used for postprocessing
- **656x** improvement in time-to-solution over previous SOTA




QPU execution:
300,983 circuits
3.8 days (IonQ Forte)

GPU post-processing:
179,858 shadows
13,200 GPU-hours (H200)

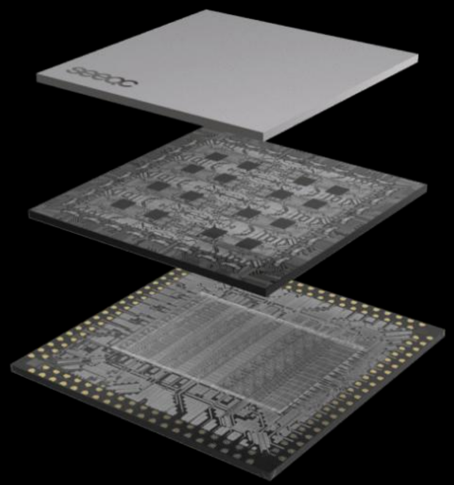
arXiv:2506.22408v1

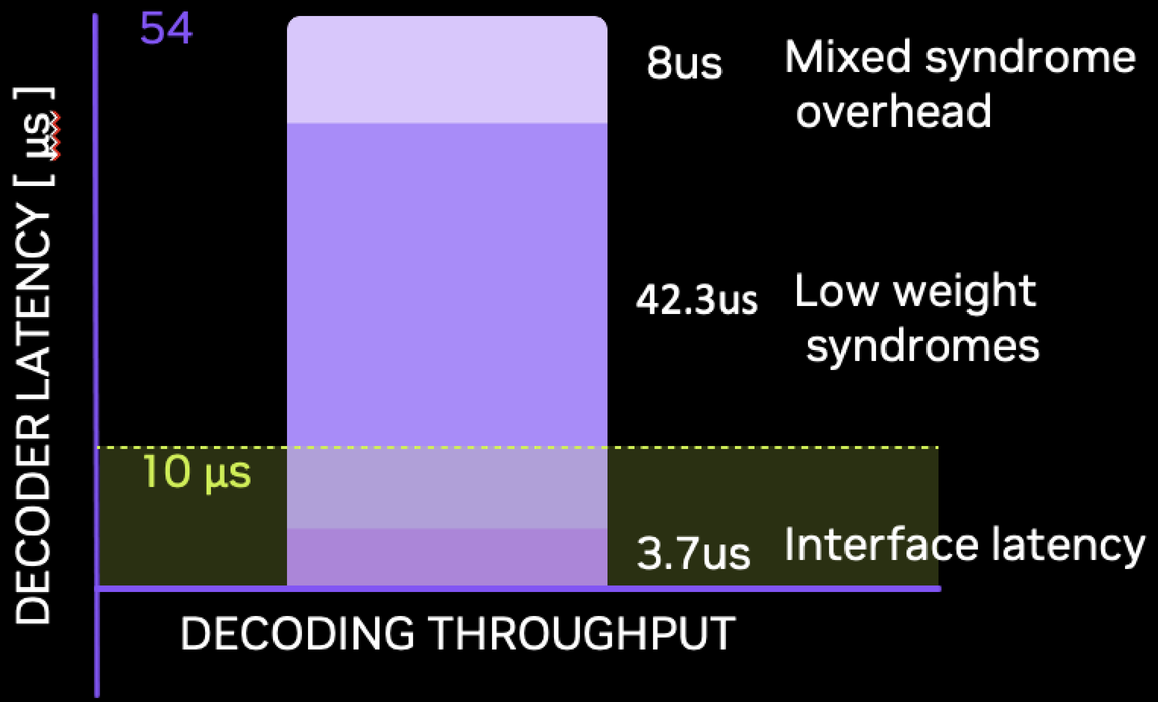
# State of the Art All Digital Quantum GPU Interface

Developed all-digital QPU-GPU interface

Emulated Distance-3 surface code QPU

State of the art latency with 1,000x throughput improvement, using CUDA-Q QEC decoder





# Accelerating Quantum Application Development

Through CUDA-Q development platform

NVIDIA + BASF

*Hybrid algorithm for* ***chemically modelling toxin-removing catalysts****.*

| 200X | 6X | 60+ | |
|---|---|---|---|
| Speedup with DGX Cloud vs CPU | Larger sim with CUDA-Q vs their HPC SC | Qubit TN-MPS simulation | Only 1 day onboarding to run small sims |

NVIDIA + HSBC

***165+ qubit*** *QC simulation for increasing* ***fraud detection accuracy***

| | 4% | 2% |
|---|---|---|
| Quantum algorithm beats comparative classical model | Reduction in false positive | Increase in true positives |

# The NVIDIA Quantum Platform

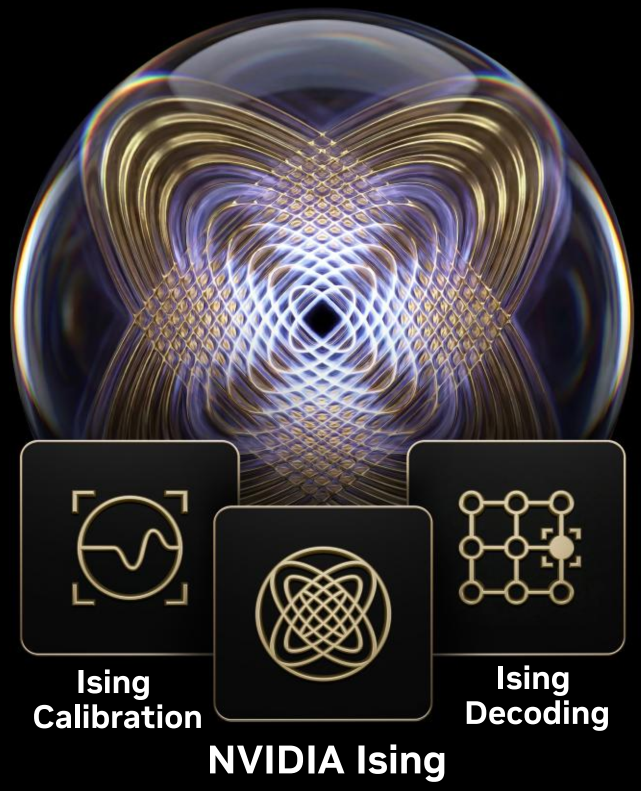
Bringing AI Supercomputing to Enable Useful Quantum Computing

**CUDA-QEC and CUDA-Q Algorithms**
Turnkey QEC Research and Application Development

**CUDA-Q**
Open-Source Software Platform for Accelerated Quantum Supercomputers

**cuQuantum**
Accelerated Quantum Simulation/Emulation on GPU

**NVQLink**
Reference Architecture for Low Latency Integration



# CUDA-Q

The platform for accelerated quantum computing

## CUDA-Q

Libraries | Programming Model | Tools | QEC | QPU Design | Infrastructure

### Simulation

cuQuantum

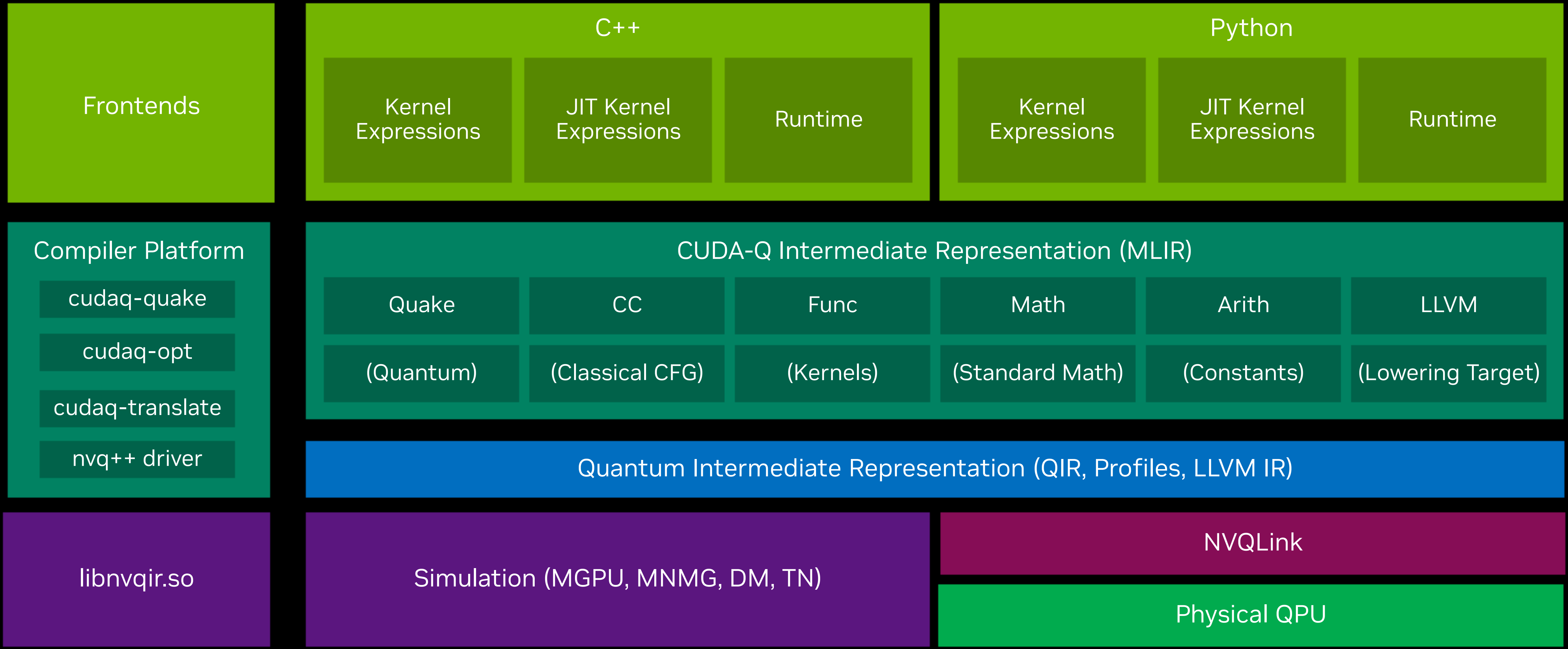
### QPU Hardware

OQC, QUANTINUUM, ORCA Computing, ALICE & BOB, IONQ, QUANTUM BRILLIANCE, PASQAL, IQM, QuEra Computing Inc., seeqc, rigetti, Infleqtion, Anyon Technologies

## AI Supercomputing

# CUDA-Q

## The CUDA-Q stack



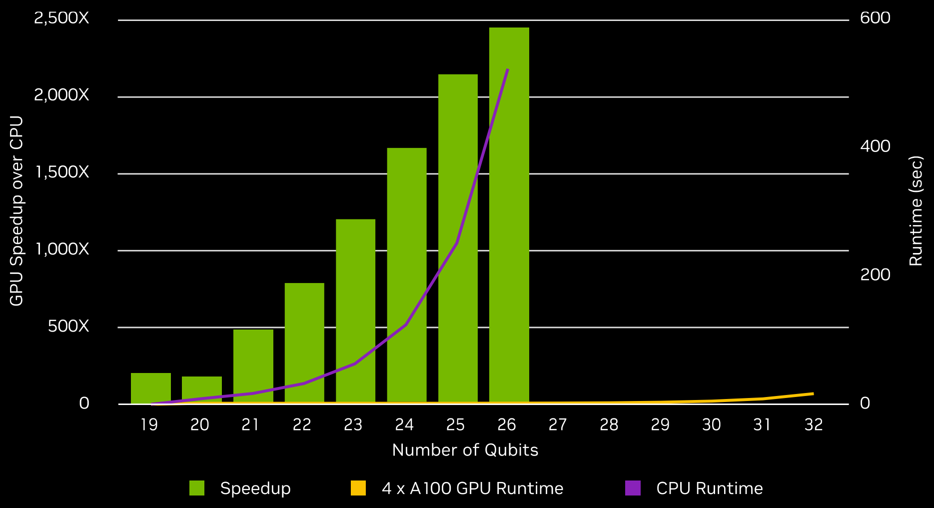
# CUDA-Q

The platform for accelerated quantum computing

## Features

- **Python and C++**
  - Access via familiar & powerful languages
- **QPU agnostic**
  - Supports backends from all major QPU vendors and qubit types
- **GPU-accelerated** simulation
  - Quantum simulators that scale to large-scale quantum computers
- Fully **kernel system for hybrid computing interface**
  - Seamlessly combine GPU and QPU resources
- Supports **QEC HW development**
  - DGX-Quantum reference architecture allows decoder and calibration development
- Access to classical **CUDA-X libraries**
  - Conventional parts of hybrid algorithms can draw on fastest implementations
- Comprehensive **educational tools**
  - CUDA-Q Academic onboards users to accelerated quantum supercomputing

## Performance




QML workflow in CUDA-Q using multithreaded CPU versus NVIDIA A100 Tensor Core GPUs

## Getting started with CUDA-Q

**CUDA-Q Overview**
https://developer.nvidia.com/cuda-q

**CUDA-Q Academic**
https://github.com/NVIDIA/cuda-q-academic

**CUDA-Q Docs**
https://nvidia.github.io/cuda-quantum/latest/index.html

**CUDA-Q Apps**
https://nvidia.github.io/cuda-quantum/latest/using/tutorials.html

NVIDIA

# NVIDIA NVQLink

## Quantum Processors

Alice & Bob, Anyon Technologies, atom computing, diraq, Infleqtion, IONQ, OQC, ORCA Computing, Pasqal, Quandela, Quantum Motion, QuEra, rigetti, seeqc, Silicon Quantum Computing

## NVIDIA NVQLink

Berkeley Lab, Keysight, Quantinuum, Quantum Machines, QBLOX, Zurich Instruments

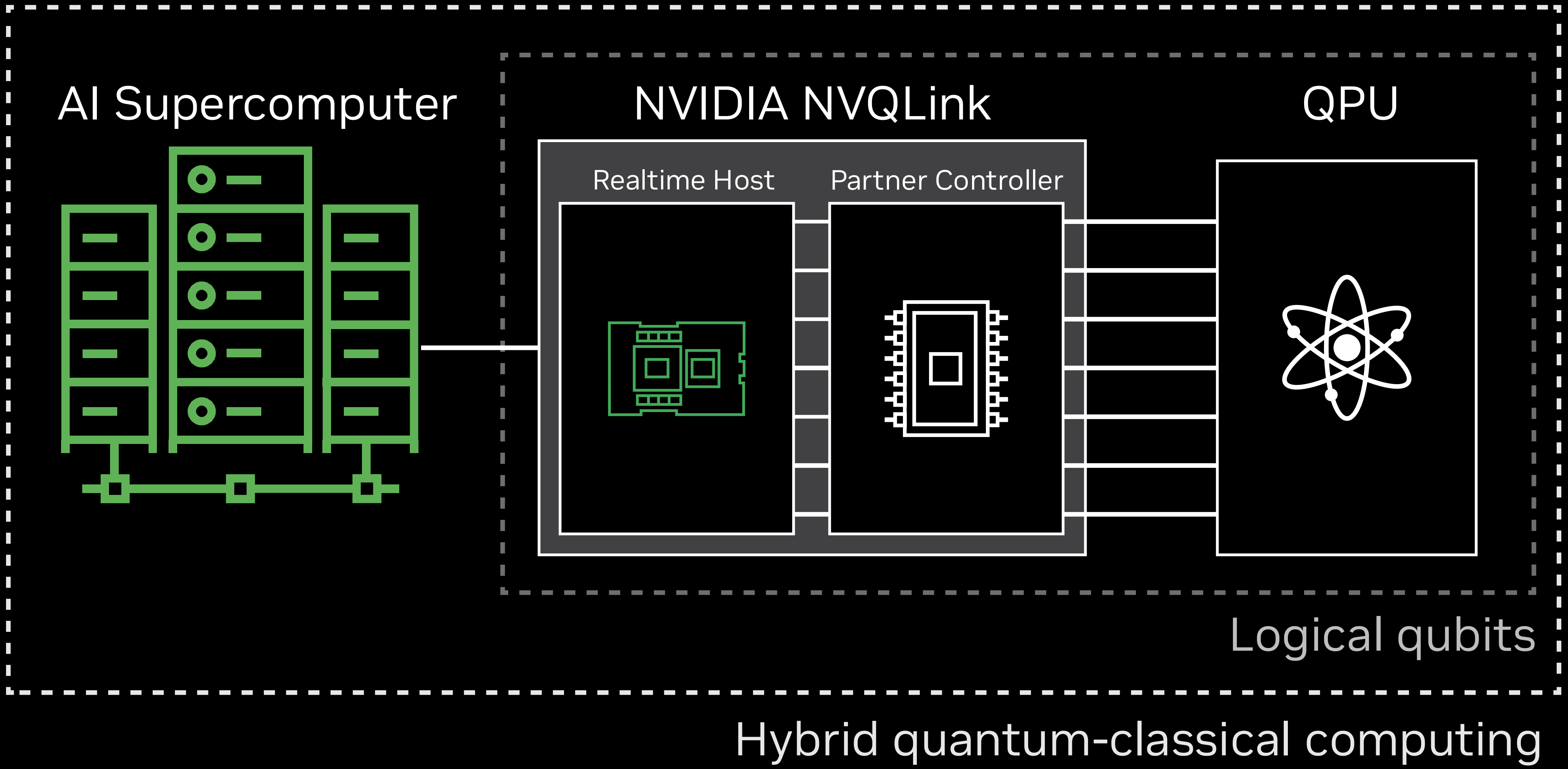
## GPU Supercomputers

AIST, Brookhaven National Laboratory, CINECA, DCAI, Fermilab, GENCI, VSB Technical University of Ostrava IT4Innovations National Supercomputing Center, Jülich Forschungszentrum, KAUST, KISTI, Lincoln Laboratory Massachusetts Institute of Technology, Los Alamos National Laboratory, NCHC, NERSC, UKRI National Quantum Computing Centre, National Quantum Computing Hub Singapore, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Pawsey, PCSS, Sandia National Laboratories, TII Technology Innovation Institute

NVIDIA

# NVQLink

The Rosetta stone for Quantum-GPU supercomputing



# NVIDIA Ising

## Open Model Family for Quantum Computing

### Ising Calibration

Vision Language Model (VLM)

### Ising Decoding

Convolutional Neural Network (CNN)

### Cookbook

Fine-Tuning, Quantization, Inference Workflows

### Open Research

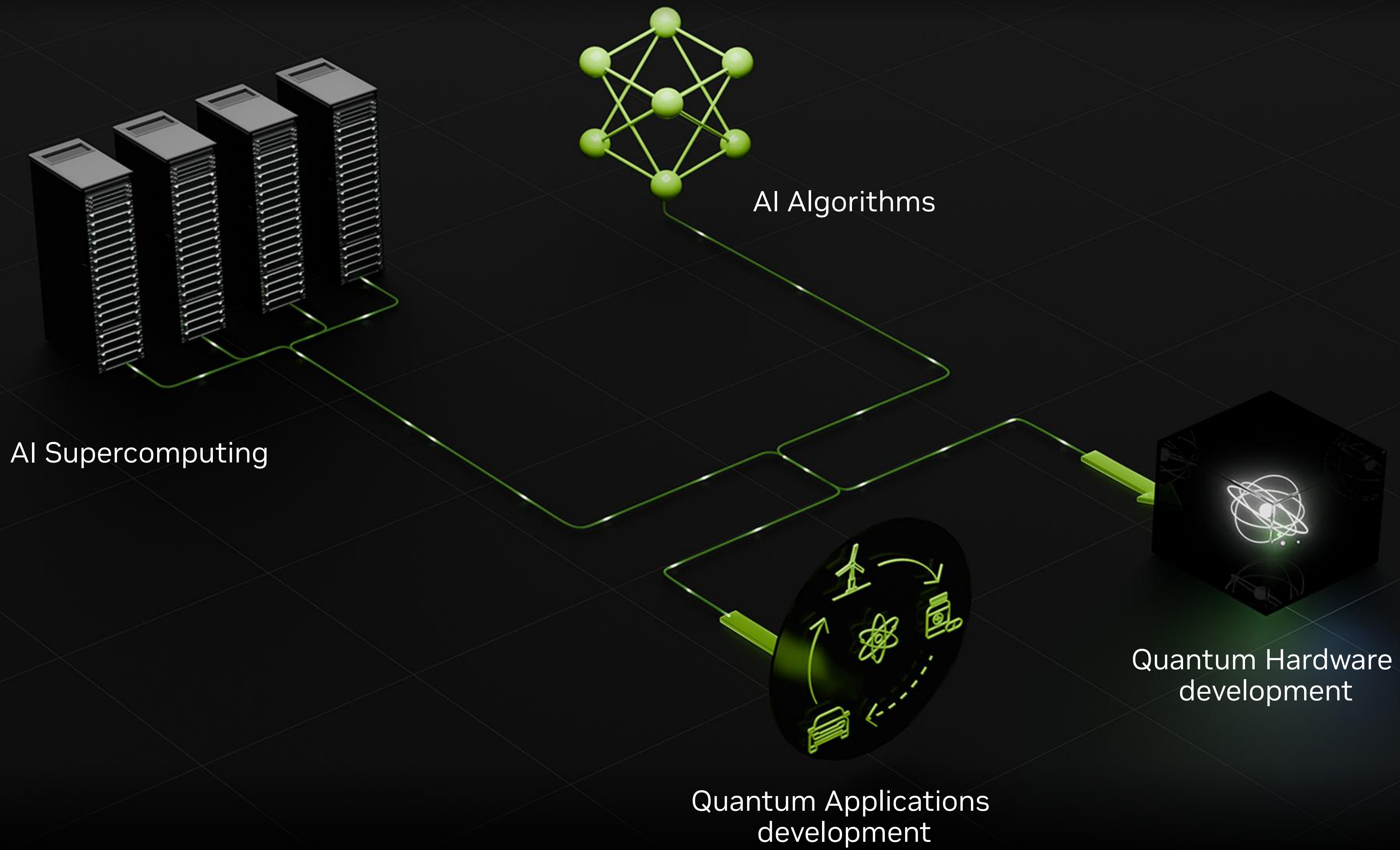
Open Models and Papers

### Open Data

Benchmark Data and Training

# AI for QC

Bringing advances in AI to Quantum Computing

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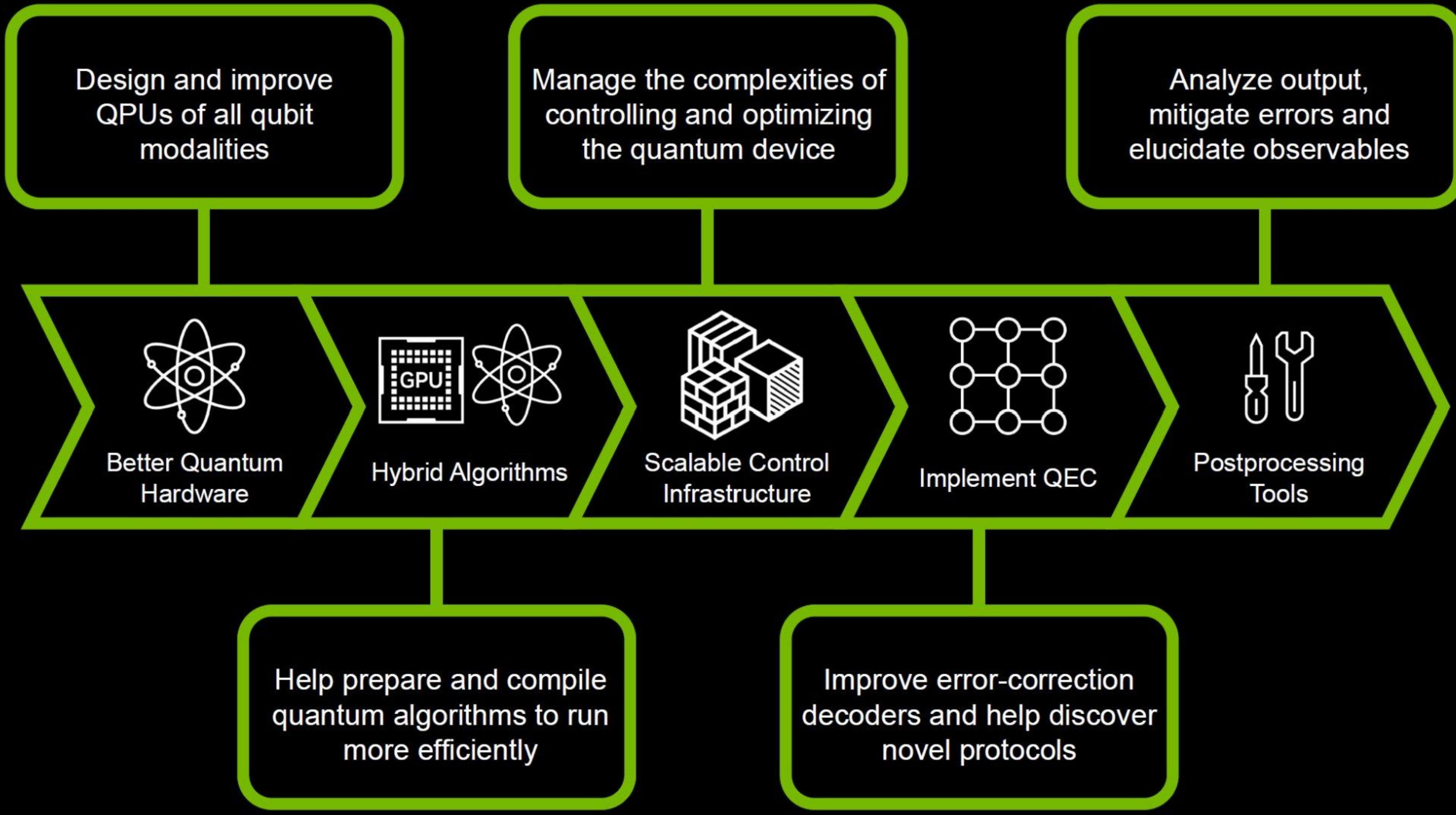
# Artificial Intelligence for Quantum Computing

arXiv:2411.09131



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